AD-A114 378 HONEYWELL SYSTEMS AND RESEARCH CENTER MINNEAPOLIS MN F/G 5/9
TEAM TRAINING FOR COMMAND AND CONTROL SYSTEMS. VOLUME IV. RECOM--ETC(U)
APR 82 J A MODRICK, S R HOLLINGSWORTH F33615-79-C-0025

UNCLASSIFIED AFHRL-TP-82-10 NL

1 of 2
AD
A114378

AFHRL-TP-82-10

AIR FORCE

HUMAN RESOURCES

TEAM TRAINING FOR COMMAND AND CONTROL SYSTEMS: RECOMMENDATIONS FOR SIMULATION FACILITY

By

Sam R. Hollingsworth
John A. Modrick
David R. Baum

Honeywell Systems and Research Center
2600 Ridgeway Parkway
P.O. Box 312
Minneapolis, Minnesota 55440

LOGISTICS AND TECHNICAL TRAINING DIVISION
Logistics Research Branch
Wright-Patterson Air Force Base, Ohio 45433

April 1982

Final Technical Paper

LABORATORY

AIR FORCE SYSTEMS COMMAND
BROOKS AIR FORCE BASE, TEXAS 78235

82 05 12 074

NOTICE

When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely Government-related procurement, the United States Government incurs no responsibility or any obligation whatsoever. The fact that the Government may have formulated or in any way supplied the said drawings, specifications, or other data, is not to be regarded by implication, or otherwise in any manner construed, as licensing the holder, or any other person or corporation; or as conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

The Public Affairs Office has reviewed this paper, and it is releasable to the National Technical Information Service, where it will be available to the general public, including foreign nationals.

This paper has been reviewed and is approved for publication.

ROLAND W. DENSON
Contract Monitor

ROSS L. MORGAN, Technical Director
Logistics and Technical Training Division

DONALD C. TETMEYER, Colonel, USAF
Chief, Logistics and Technical Training Division

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER AFHRL-TP-82-10	2. GOVT ACCESSION NO. AD-A114 378	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) TEAM TRAINING FOR COMMAND AND CONTROL SYSTEMS: RECOMMENDATIONS FOR SIMULATION FACILITY		5. TYPE OF REPORT & PERIOD COVERED Final 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Sam R. Hollingsworth John A. Modrick David R. Baum		8. CONTRACT OR GRANT NUMBER(s) F33615-79-C-0025
9. PERFORMING ORGANIZATION NAME AND ADDRESS Honeywell Systems and Research Center 2600 Ridgeway Parkway, P.O. Box 312 Minneapolis, Minnesota 55440		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 62205F 17100347
11. CONTROLLING OFFICE NAME AND ADDRESS HQ Air Force Human Resources Laboratory (AFSC) Brooks Air Force Base, Texas 78235		12. REPORT DATE April 1982 13. NUMBER OF PAGES 116
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) Logistics and Technical Training Division Air Force Human Resources Laboratory Wright-Patterson Air Force Base, Ohio 45433		15. SECURITY CLASS. (of this report) Unclassified 15a. DECLASSIFICATION DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

command and control
simulation exercises
simulation technology
team training

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

There is a need for empirical research on methods for improving team training (T^2) for operators of Air Force command and control (AFC^2) systems. This paper presents recommendations for a computerized, general-purpose simulation system to be used by the Air Force to support AFC^2T^2 research. A high-level functional description of the hardware and software comprising the recommended research facility is provided, and interface requirements for simulation exercise controllers, AFC^2 team members, and other personnel who would interface with the system are discussed. In addition, the technical feasibility and risk associated with the major hardware and software components of the system, AFC^2T^2 research issues that can be addressed through the use of the recommended research facility, and the potential impact of advanced simulation technology on AFC^2T^2 programs are also discussed. Four additional

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified

Item 20 (Continued):

technical papers document the AFC^{2}T^2 research: AFHRL-TP-82-7, AFHRL-TP-82-8, AFHRL-TP-82-9, and AFHRL-TP-82-11.

AFHRL Technical Paper 82-10 April 1982

TEAM TRAINING FOR COMMAND AND CONTROL SYSTEMS: RECOMMENDATIONS FOR SIMULATION FACILITY

By

Sam R. Hollingsworth
John A. Modrick
David R. Baum

Honeywell Systems and Research Center
2600 Ridgeway Parkway
P.O. Box 312
Minneapolis, Minnesota 55440

Reviewed by

Roland W. Denson
Research Psychologist
Ground Operations Section

Submitted for Publication by

William B. Askren
Senior Scientist
Logistics Research Branch

PREFACE

Throughout the text of this paper, reference is made to volumes I through V. These volumes have been published as separate technical papers identified as follows:

Volume I

Baum, D.R., Modrick, J.A., & Hollingsworth, S.R. *Team training for command and control systems: Status*. AFHRL-TP-82-7. Wright-Patterson AFB, OH: Logistics and Technical Training Division, Air Force Human Resources Laboratory, April 1982.

Volume II

Modrick, J.A., Baum, D.R., & Hollingsworth, S.R. *Team training for command and control systems: Recommendations for research program*. AFHRL-TP-82-8. Wright-Patterson AFB, OH: Logistics and Technical Training Division, Air Force Human Resources Laboratory, April 1982.

Volume III

Baum, D.R., Modrick, J.A., & Hollingsworth, S.R. *Team training for command and control systems: Recommendations for application of current technology*. AFHRL-TP-82-9. Wright-Patterson AFB, OH: Logistics and Technical Training Division, Air Force Human Resources Laboratory, April 1982.

Volume IV

Hollingsworth, S.R., Modrick, J.A., & Baum, D.R. *Team training for command and control systems: Recommendations for simulation facility*. AFHRL-TP-82-10. Wright-Patterson AFB, OH: Logistics and Technical Training Division, Air Force Human Resources Laboratory, April 1982.

Volume V

Baum, D.R., Modrick, J.A., & Hollingsworth, S.R. *Team training for command and control systems: Executive summary*. AFHRL-TP-82-11. Wright-Patterson AFB, OH: Logistics and Technical Training Division, Air Force Human Resources Laboratory, April 1982.

This paper is the fourth of five volumes prepared by Honeywell to document the results of a research program to evaluate the current status of team training (T^2) for operators of complex Air Force Command and Control (AFC^2) systems, and to make recommendations for enhancing the AFC^{2}T^2 process. The research was performed for the Air Force Human Resources Laboratory under contract F33615-79-C-0025.

This paper presents recommendations for a general-purpose research/training device to be used by the Air Force to support empirical AFC^{2}T^2 research. The research effort supports a major new Air Force Human Resources Laboratory (AFHRL) research and development program whose primary objective is to improve T^2 technologies in areas particularly relevant to Air Force combat readiness. The program objective requires the establishment of a baseline data base on how T^2 is currently conducted in the Air Force, how it is developed, implemented, and evaluated. Because Air Force teams vary greatly in size, structure, and functions, it would be impractical to collect data on the training provided to all of them. Rather, the scope of this research effort had to be directed at an area with potential high payoff for increased combat readiness and effectiveness. The area of command and control (C^2) was chosen as a point of departure for the research because C^2 teams tend to be well defined structurally, are of a manageable size, and perform functions highly representative of Air Force mission needs. Furthermore, as the research effort unfolded, limited time and resources made it necessary to focus on tactical and air defense C^2 systems to the exclusion of strategic C^2 systems. Thus, the C^2 systems surveyed are, or in the case of planned systems will become, Tactical Air Command (TAC) resources.

The goal of this effort was to develop a picture, through interview and observation, of how AFC^2T^2 is currently developed, implemented, and evaluated, and what C^2 training needs will arise in the future. Based on this picture, strengths and weaknesses of AFC^2T^2 were identified, and recommendations were developed in three areas:

- T^2 research and development program
- Resolution of issues using current techniques/technologies
- Simulation technology development for C^2T^2

These recommendations will form the foundation for future research by AFHRL into the performance of C^2 teams and systems. The research will encompass training technology, performance measurement techniques for C^2 teams and systems, human resources issues in the design and operation of C^2 systems, and training of command/decision skills. The ultimate goal of this program is to improve technologies in areas of team and human factors related to the combat effectiveness of Air Force C^2 operations.

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (concluded)

LIST OF ILLUSTRATIONS

LIST OF TABLES

LIST OF ACRONYMS

ABCCC	Airborne command and control center
ACC	Artillery control console
AFC^2	Air Force command and control
AFC^2T^2	Air Force command and control team training
AFHRL	Air Force Human Resources Laboratory
APQ	Automatic positionally qualified
ARI	Army Research Institute
AWACS	Airborne warning and control system
C^2	Command and control
CAI	Computer-assisted instruction
CAS	Close-air support
CATTS	Combined-arms Tactical Training System
CBT	Computer-based training
CDMO	Computer and display maintenance operator
CRC/CRP	Control and reporting center/post
CRT	Cathode ray tube
ECM/ECCM	Electronic countermeasures/electronic counter-countermeasures
EW	Electronic warfare
FACP	Forward air control post
NWGS	Naval Warfare Gaming System
OJT	On-the-job training
RICMO	Radar input countermeasures operator
SAGE	Semi-automated ground environment
SAINT	Systems Analysis of Integrated Networks Tasks
SAM	Surface-to-air missile

LIST OF ACRONYMS (concluded)

SCAR	Strike control and armed reconnaissance
SEPP	System exercise problem package
SGSS	SOTAS Ground Station Simulator
T^2	Team training
TAC	Tactical Air Command
TACC	Tactical air control center
TACP	Tactical air control party
TTS	TACFIRE Trainer Set
VFMED	Variable-format message entry device

CHAPTER I

INTRODUCTION

There is a need for a facility to be used by the Air Force to support empirical AFC^2T^2 research. The facility should be a general-purpose, computerized system that can be used to address the variety of research issues listed in Table 1. The issues are summarized briefly in Chapter 5 and discussed in detail in Volumes II and III. The purpose of the present volume is to present a high-level, functional design of a system that would support such a research program.

Figure 1, which has been reproduced from Volume I, illustrates the wide range of contexts within which AFC^2T^2 occurs. Many of the issues listed in Table 1 are appropriate in more than one cell in Figure 1. The research facility should ideally support research in all cells in the figure, but resource constraints and simulation technology limitations will probably force a more limited scope.

We recommend that the research facility support team research involving AFC^2 teams comparable in size, function, and configuration to the principal members of an AWACS, CRC, CRP, or TACC team. Such teams consist of weapons, surveillance, command, and support subteams. If each subteam is assumed to consist of three individuals, the facility should support 12 team members. Each team member should have a console that is functionally similar to the console used in operational or planned future AFC^2 systems. The system should have the flexibility

TABLE 1. RESEARCH PROJECTS TO BE SUPPORTED BY THE RECOMMENDED AFC^{2}T^2 RESEARCH FACILITY

1. Performance measurement for C^2 operators, teams, and systems
   - Individual performance measurement
   - Team performance measurement
   - System effectiveness measurement
   - Contribution of individual and team performance to system effectiveness
2. C^{2}T^2 program objectives and requirements
   - Media selection analysis
   - Sequencing of instructional material
   - Interaction of team type and task type with instructional strategy
   - Development of representative problem sets
3. C^{2}T^2 simulation exercise requirements
   - Definition of training requirements for simulation exercises
   - Physical fidelity
   - Tactical fidelity
   - Automated operator and team performance assessment
   - Feedback techniques
   - Wargaming
   - Part-whole task exercises
4. Man-machine design for C^2 systems and teams
   - Interaction of team type and task type
   - Information flow analysis
   - Functional allocation
   - Operator and team decision aids
   - Operator and team consoles, communication nets, and procedures
5. Automated C^{2}T^2 training support functions
   - Assessment of operator and team performance
   - Maintenance of performance records
   - Control of lesson and exercise sequencing
   - Adaptive training and testing
   - Monitoring and guidance of student performance
6. Personnel requirements for C^2 teams
   - Prerequisite skill and knowledge requirements
   - Remediation techniques

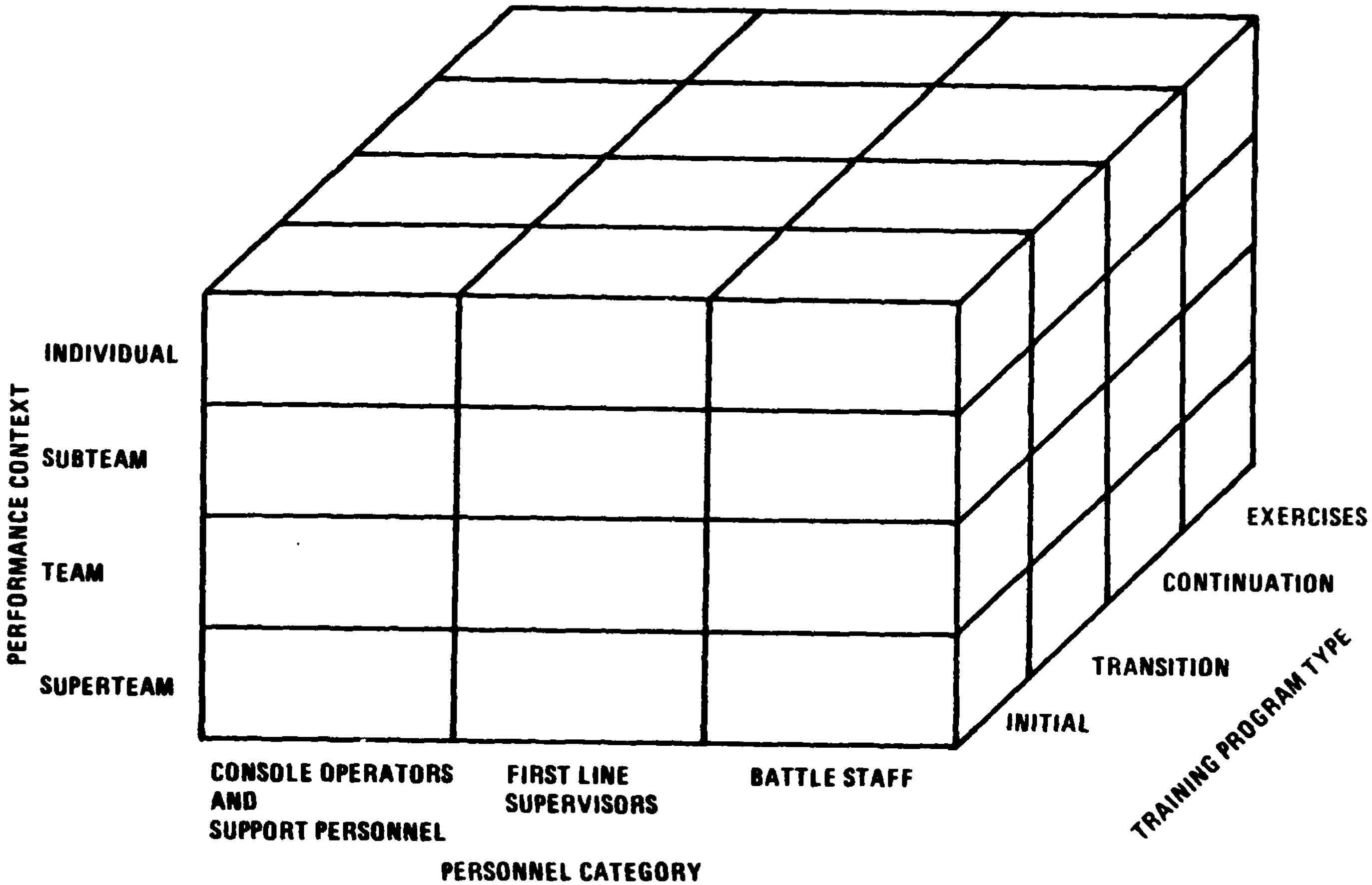

Figure 1. Training Contexts to which Instructional System Development May be Applied

to allow researchers to determine the number and capabilities of each operator type on the basis of research requirements.

In addition to the AFC^2 team members, the research facility should include consoles for computer operators, researchers observing team behavior and performing umpire functions, role players and script readers, and software developers and maintenance personnel.

The team behavior should occur within the context of a simulated tactical scenario. The scenario would be embodied in software that simulates tactical events, provides imagery and tactical information to exercise controllers and AFC^2 team members, and collects and analyzes individual and team performance data.

OVERVIEW OF THE RECOMMENDED AFC^2T^2 RESEARCH FACILITY

The recommended research facility would consist of three primary subsystems:

- Hardware
- Personnel
- Software

Figure 2 provides an overview of these subsystems, which are described briefly in the following paragraphs.

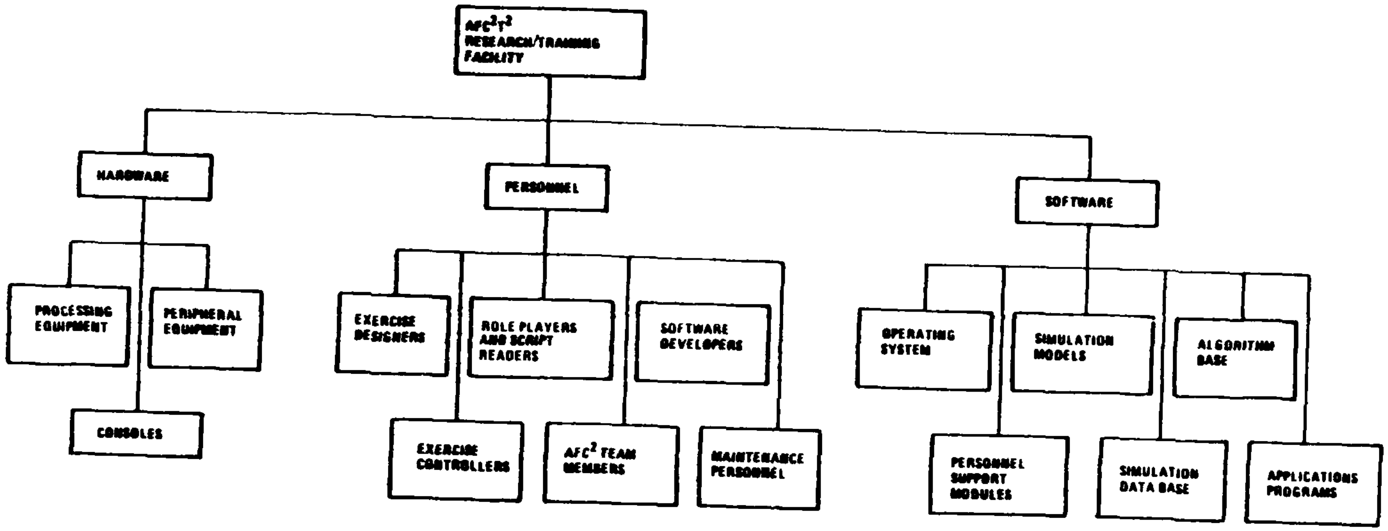

Figure 2. Overview of Hardware, Personnel, and Software Comprising Recommended AFC^{2}T^2 Research Facility

Hardware

The system would be driven by a hardware system consisting of processing equipment, operator consoles, and other peripheral equipment (Figure 3). The processing equipment should include a central processing unit or, if a distributed processing architecture is followed, a number of minicomputers. We recommend a distributed processing approach for two reasons:

- The system can be procured and developed incrementally over time
- A hardware failure in one component is not as likely to cause the entire system to fail

Each operator console would consist of a CRT (or equivalent) display capable of presenting dynamic alphanumeric, graphic, and simulated radar information; an alphanumeric keyboard; a function keyboard; a trackball (or equivalent device); and voice communication gear. Communication gear should include headsets, control panels, and automatic voice recognition/synthesis devices. All consoles should be identical, and should be capable of supporting the diverse classes of users listed in Figure 2. In addition to consoles for individual operators, large-screen displays that can be used by sets of operators should also be provided.

Peripheral equipment should include mass storage devices, a digitizer and map bug, a high-speed printer, a device for the output of hard copies of graphic information, and all required interface equipment.

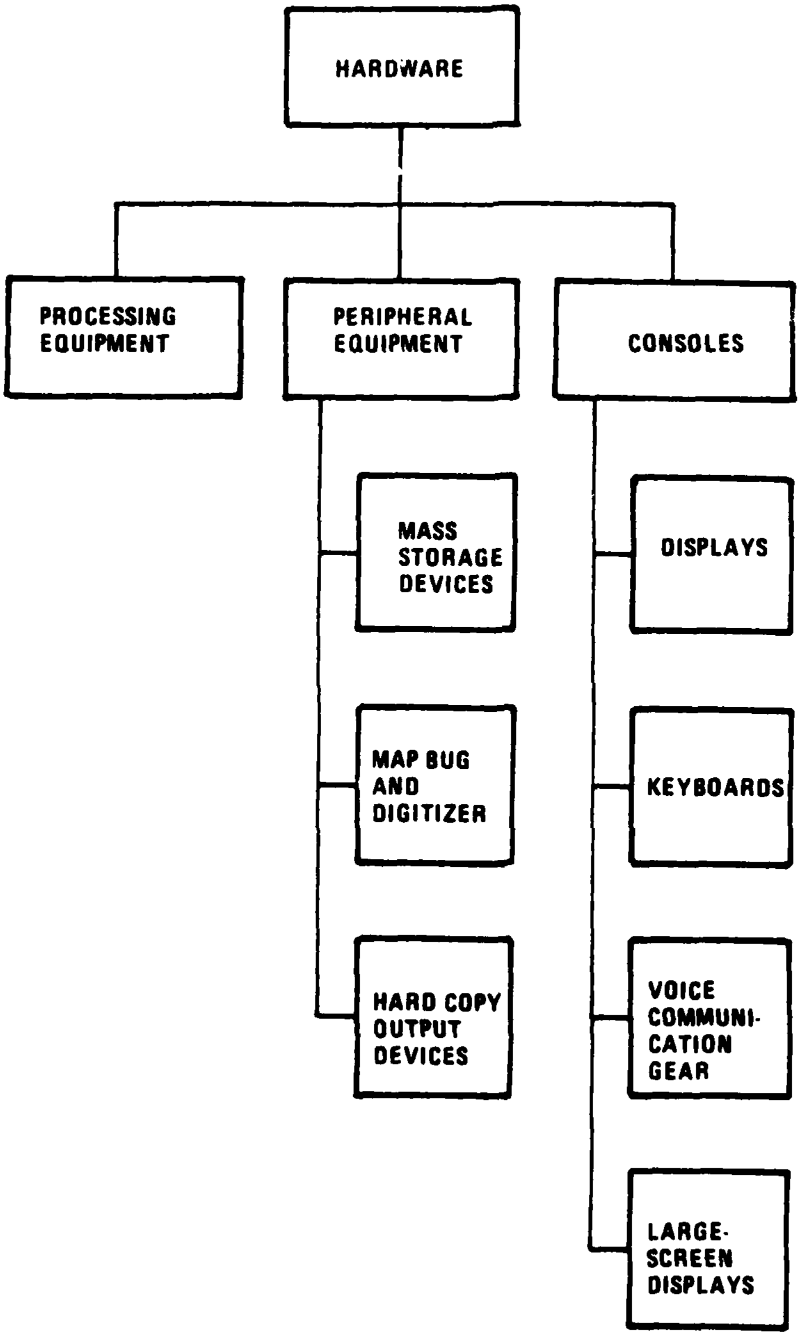

Figure 3. Hardware Components of the Recommended AFC^2T^2 Research Facility

All hardware, including operator consoles, should be commercial, off-the-shelf equipment. It does not need to be ruggedized to meet military standards, nor does it need to match existing or anticipated C^2 equipment exactly in terms of appearance or operating characteristics. This approach should minimize acquisition costs and delays, and reduce maintenance problems.

A schematic overview of the recommended system is presented in Figure 4. The figure illustrates a case in which there are nine AFC^2 team consoles and four consoles for exercise controllers. The precise number of each type of console would depend on the details of research requirements.

Personnel

As indicated above, the research facility would be staffed by several types of users. Figure 5 illustrates the major categories. Exercise designers include the research staff and personnel from external agencies who are sponsoring particular exercises. Their primary function would be to specify the team configuration, research variables, and background conditions to be tested.

Exercise controllers include computer operators and researchers. The computer operators would be responsible for loading, starting, and monitoring the hardware and software before and during an exercise. The researchers would monitor individual and team behavior, perform umpire functions, and control and monitor simulation events during an exercise.

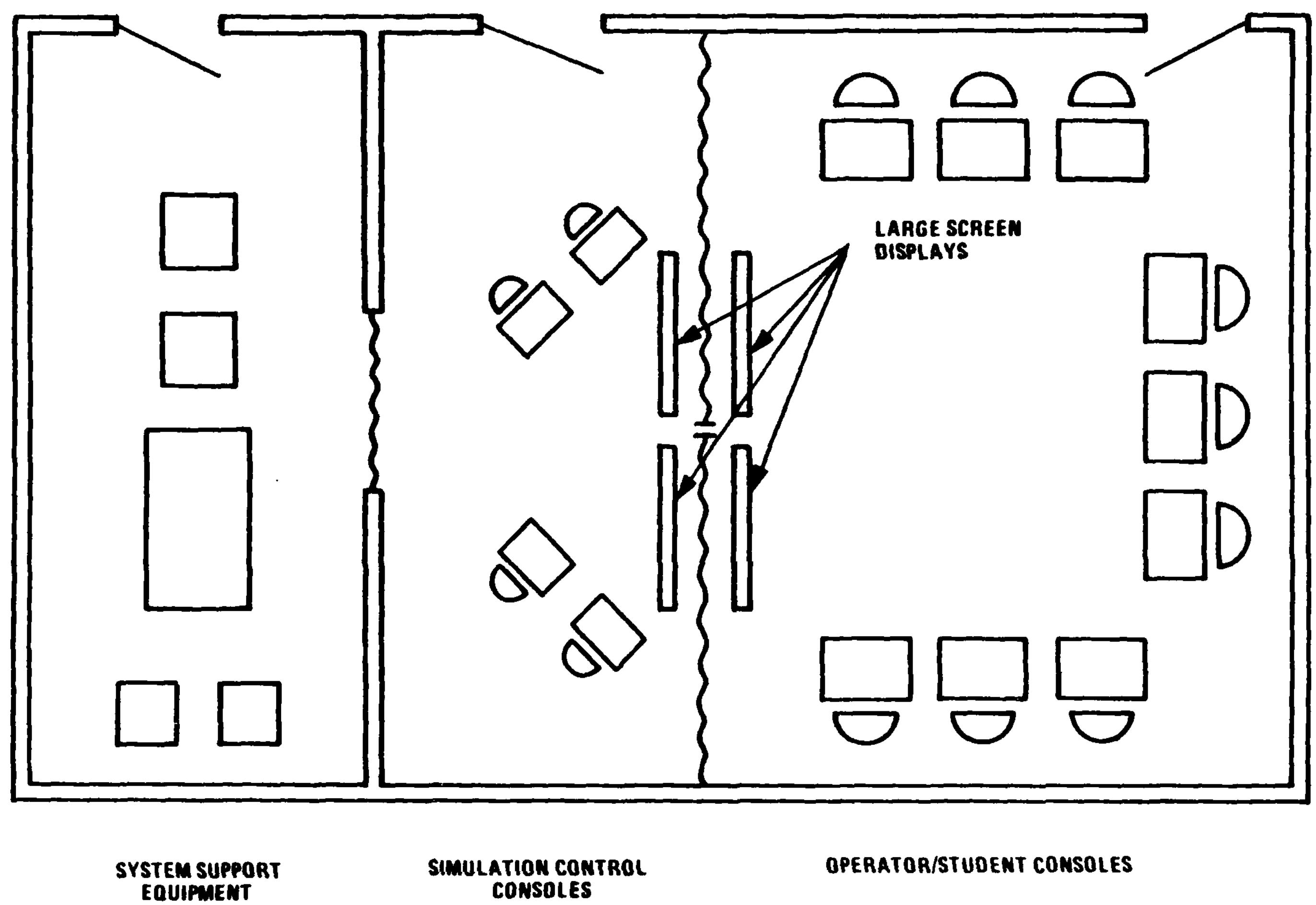

Figure 4. Schematic Overview of the Recommended AFC^2T^2 Research Facility (Not drawn to scale)

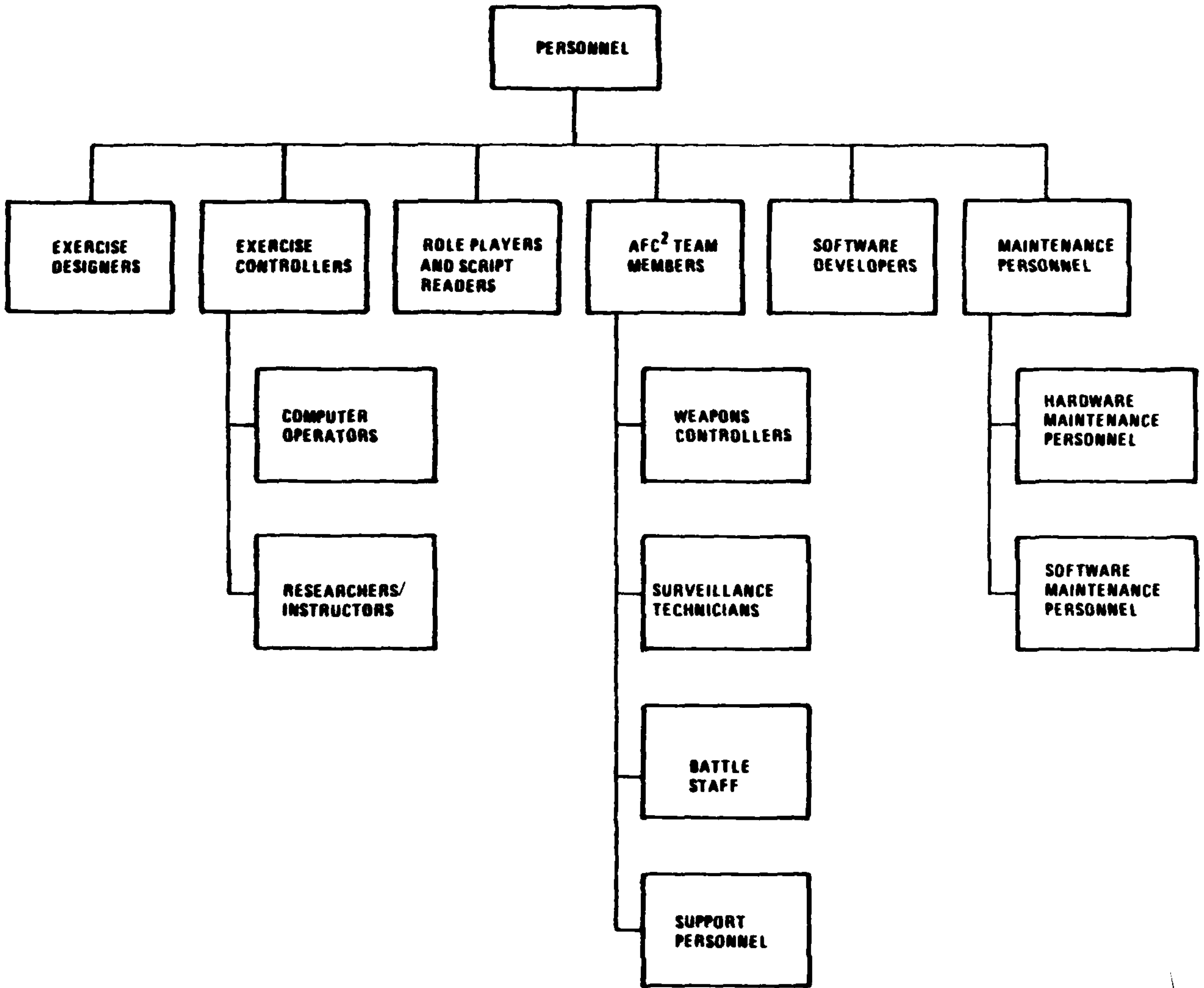

Figure 5. Categories of Personnel for the Recommended AFC^2T^2 Research Facility

Role players and script readers would provide voice inputs to AFC^2 team members, and respond to voice outputs from the team. Script readers would read statements from prepared text at specified times during an exercise. Role players would be relatively less constrained, and would make free voice inputs as appropriate during an exercise.

The AFC^2 team members would, in general, be military personnel drawn from schools or operational units as dictated by research requirements.

The software developers would be responsible for creating and modifying the software system.

Maintenance personnel would be responsible for maintaining the hardware and software subsystems. Hardware maintenance could be performed by vendor personnel under a service contract.

It is likely that an individual would perform several functions. A researcher would be likely to participate both in the exercise design and exercise control functions, and could also serve as a script reader or role player. A software developer could also act as computer operator and software maintainer.

The staff operating the research facility would consist of a mix of in-house, contractor, and military personnel in ratios determined by research needs.

Software

The software subsystem would consist of the modules illustrated in Figure 6. An operating system is necessary, but its characteristics are relatively unimportant at the present level of discussion. It should provide adequate programming, editing, and debugging capabilities to expedite the software development process.

The personnel support modules should control the consoles and enable the functions of all participants. These modules would control the display of all information on all consoles, and would interpret all operator inputs. The modules would require a great deal of flexibility so that they could be reconfigured to support a variety of users.

The simulation models would comprise the "driver scenario" for simulation exercises. The function of the models would be to generate tactical events that would drive the behavior of the AFC^2 team. Each model should be generalized in the sense that parameter values can be readily modified without changing the structure of the model itself. A generalized sensor model, for example, would contain parameters for range, resolution, and target location accuracy. The same model could be used to simulate a variety of radar systems, each of which is characterized by a different set of parameter values. A similar strategy should be followed in designing the other classes of models listed in Figure 6.

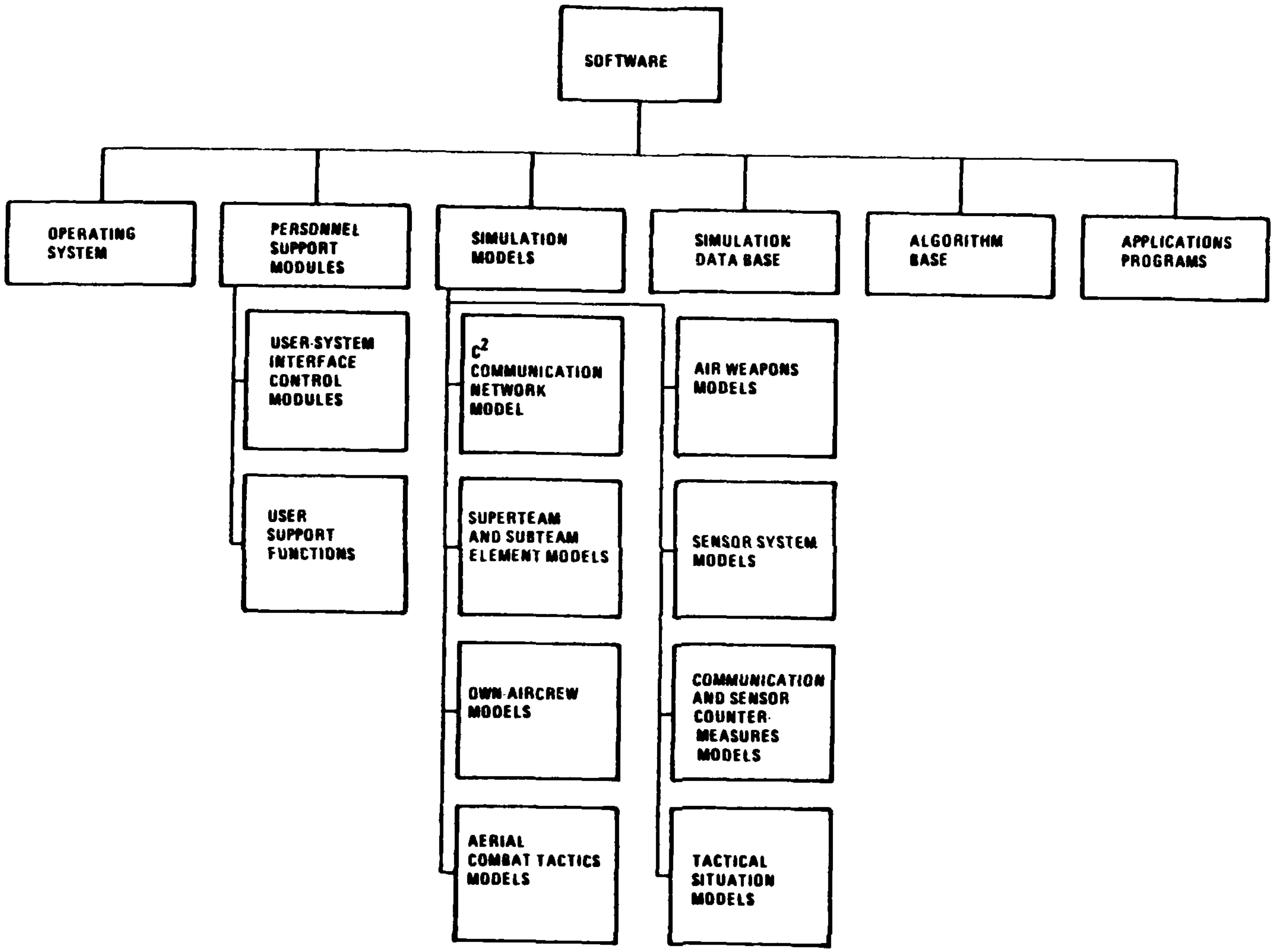

Figure 6. Software Components of the Recommended AFC^2T^2 Research Facility

The driver scenario could be changed radically from one exercise to another by changing the parameter values of the models. The values should be stored in a simulation data base that can be accessed and modified conveniently by exercise designers.

The simulation models would also draw on a set of algorithms. As with the simulation data base, the algorithm base should be readily modifiable to support a wide range of research requirements.

Software development personnel should have the capability of preparing and using special-purpose applications programs as the need arises.

ORGANIZATION OF VOLUME IV

Chapter I of this volume has presented an overview of the hardware, personnel, and software subsystems of a recommended AFC^2T^2 research facility. Chapter II describes its functions and configuration in more detail. Chapter III discusses the potential impact of advanced simulation technology on AFC^2T^2 programs. Chapter IV evaluates the technical risk associated with the major features of the system, and Chapter V summarizes the research issues that the system could be used to address.

CHAPTER II

CONFIGURATION AND FUNCTIONS OF THE RECOMMENDED AFC^2T^2 RESEARCH FACILITY

This chapter describes the configuration and functions of the recommended AFC^2T^2 research facility. The discussion is organized into three sections:

- Hardware
- Personnel
- Software

The discussion is intended to be at a conceptual level that can be developed subsequently into a detailed design specification. Such a specification would require the acquisition and analysis of additional information about AFC^2 team functions, the tactical environment, computer capabilities, and empirical research plans. The foundation for detailed research plans is provided in Volumes II and III.

HARDWARE

The recommended hardware system would consist of processing equipment, operator consoles, and other peripheral equipment. Processing and peripheral equipment are discussed briefly below. User consoles are discussed separately because of their central importance.

Processing and Peripheral Equipment

The hardware supporting the simulator should include central processing equipment, mass storage media, a map bug and digitizer, high-speed printer, a device for the output of graphic information, and any required interface equipment. The central processor should have the capacity and speed to drive the scenario events at a rate that is appropriate for the research/training requirements of particular exercises. The architecture of the system is largely irrelevant at the present level of discussion, except that a distributed processing system may be well-suited to the research/training applications of the simulator. A relatively powerful central computer that generated simulation events and controlled the flow of information could communicate with less powerful computers that handled display requirements and operator interaction at individual consoles, for example. This approach would have the advantage of allowing the facility to be developed and tested incrementally, and it would also reduce the probability that a single hardware failure would cause the entire system to go down.

The system should include standard mass storage equipment for recording all software and performance data.

A map bug and digitizer should be provided for the entry of graphic information. Map contours, the initial distribution of Blue and Red forces, and other data would be entered through this channel.

Output devices should include a high-speed printer and a device for printing graphic data. The printer would be used for software development and maintenance purposes, as well as for printing performance data. The other devices could be a digital plotter or, preferably, a photocopy unit that would reproduce the contents of a specified CRT display screen. This would enable the reproduction of graphics files and, more importantly, of performance data. A plot of the relative paths of targets and interceptors could be generated and distributed to trainees for feedback, for example.

All hardware should be standard, off-the-shelf commercial equipment. There appears to be no compelling reason to invest in militarized, ruggedized equipment for the research applications that are envisioned for the simulator. The use of standard commercial equipment should ease acquisition and maintenance problems.

User Consoles

The recommended system should include several consoles. The precise number would depend on resource constraints and research requirements, but the goal is to provide a console for each of the key members of an AFC^2 team comparable to an AWACS, CRC, CRP, or TACC. This would include weapons, surveillance, command, and selected support subteam members (recorders, tellers, plotters, radio operators, radar technicians, computer technicians).

In addition to the AFC^2 team members, other categories of system users will also require consoles (See Figure 5). Because the relative proportion of each category will vary widely across research programs and across phases within a program, we recommend that the physical configuration of consoles remain constant for all users. Identity among the consoles would allow the mix of personnel to be changed to meet varying research requirements and it would also reduce system development and maintenance costs. Modification of the functions of a console to adapt to the needs of specific users would be done by substituting software modules and subroutines. User consoles should include the following components:

- Display
- Keyboard
- Voice communication gear

In addition to these components, large-screen displays would present information to multiple users. Each component is discussed below.

Display--The console display should be capable of presenting simulated radar imagery, graphics, and alphanumerics. As currently envisioned, a CRT screen would present "white" imagery on "black" background as is the case with most current and anticipated systems (black and white are intended to mean the two tones used on displays with light imagery on a dark background). The intensity of the display should be adjustable. In addition, the capability for reverse video (dark patterns on a light background) and color should be considered as growth options for expanding the range of research issues that can be addressed.

Required display capabilities do not vary significantly across control, surveillance, and battle staff operators. The display should be capable of presenting graphic and alphanumeric information. Graphic information would include simulated radar returns, map boundaries and terrain features, aircraft track identification data, and any other information deemed appropriate by the researcher. If the simulator is to be used to simulate older C^2 systems, the display should have the capability of representing both "raw" and synthetic radar imagery. However, since recent and anticipated C^2 systems present synthetic imagery exclusively, we feel that the capability to simulate raw returns is not required.

Alphanumeric information on an AFC^2 team member's display should include that which would normally be provided during a mission: operator data entries and commands, error messages and warnings to the operator, and any feedback that is peculiar to the research setting. Feedback would be generated either automatically by the computer or manually by simulator. Although upper-case characters would be suitable for most applications, lower-case capability should not be ruled out.

Display requirements for AFC^2 team support personnel are a subset of the requirements for weapons, surveillance, and command positions. Alphanumeric and some graphics capabilities will be necessary for recorder-teller-plotter functions and for functions comparable to those performed by an AWACS airborne radar technician or communications operator. Such support personnel work primarily with tabular displays, and do not view radar or other graphic imagery.

All operator displays, except perhaps the displays for AFC^2 support personnel, should be able to present digitized map contours. The researcher would define and enter relevant contours (geopolitical boundaries, airspace boundaries, road networks, SAM perimeters, etc.). To the extent that such capabilities are appropriate for simulated AFC^2 team operations, team members should also be able to enter and modify graphics.

Some cost savings may be realized by using less expensive alphanumeric displays for operators who require no radar imagery or graphics. This approach is not recommended, however, because of the flexibility that is required for the wide range of research issues that must be addressed. It may be necessary, for example, for all displays to support weapons functions for one research project.

Keyboard--The keyboard should be partitioned into three major components: an alphanumeric keyboard, a function keyboard, and a track ball. The alphanumeric keyboard should be in standard QWERTY format. It would be used by all users to enter data and commands. The precise nature of the commands and data would vary as a function of user category. It may be desirable for the keyboard to include a separate numeric keypad.

The function keyboard should consist of a set of keys to be used by an operator to access console functions directly. Examples of functions that are relevant to weapons and surveillance operators are listed below:

- Change display scale
- Compute range and bearing between two points

- Offset the display center
- Change radar mode
- Compute intercept geometry
- Find altitude
- Attach labels to aircraft symbology
- Create graphics

A complete list would result from the consolidation of console functions lists for current and future AFC^2 systems. Simulator control personnel would have a different set of functions.

Many console functions exist, but the number of function keys may probably be reduced to 20-30 by organizing functions hierarchically. Then a top-level function could be accessed by selecting a function key and the operator would select from subordinate functions appearing in a reserved area of the display screen (a menu). An alternative to the menu-selection approach would be for a function key to initiate a dialog related to a class of functions. The operator's input during the dialog would determine the nature of the function that was invoked.

The function keys should have some provision for providing visual feedback to the operator. Two methods for doing this would be to embed lights in the key surface or to use a backlighting system. In either case, the lighting logic should indicate which of three possible states the key is in: not available, available but not in use, or available and in use. Because a common keyboard format for all users is recommended, not all keys would be functional for any given user in all research programs. The lighting logic should indicate which keys are available for use.

Function keyboard labels should clearly identify the function that will be initiated by each key. Whenever possible, the label should be a single imperative verb that characterizes the function in the operator's terms. The labels should be readily modifiable. It should be convenient to remove all labels for weapons directors, for example, and replace them with labels for script readers.

A track ball (or equivalent device) should be provided to control a cursor in the imagery area of the display. Functions requiring track ball input include range/bearing calculations and display offset functions. The performance characteristics and physical dimensions of the track ball should be similar to track balls on existing AFC^2 systems. The track ball would be used mainly by weapons, surveillance, and battle staff members of simulated AFC^2 teams. System support personnel would use track balls only occasionally, if at all.

Voice Communication Gear--Each user console should include a voice communication set consisting of a headphone, control panel, and automatic voice recognition/synthesis devices. The function keys on the control panel should be reprogrammable by the research/instructor staff to set up the communication network that is appropriate for each research/training situation. Nodes in the voice network should include the AFC^2 team members and exercise control personnel, and the communication pathways among the participants should be modifiable to meet research requirements.

In addition to human participants in the voice network, it is possible that the computer system could also participate to some extent in voice communication. This would be possible if voice recognition and synthesis were included in the system. We recommend that such capabilities be provided.

Large-Screen Displays--The function of large-screen displays would be to present tabular situation displays to exercise control personnel and to AFC^2 team members. One reason for including such displays would be to automate labor-intensive jobs, thus reducing the number of personnel required for implementing a simulation exercise. Another reason would be to provide a testbed for evaluating large-screen displays for tactical use. The number of large displays would be less than the number of consoles, and all users should be able to see all displays.

PERSONNEL

Figure 5 illustrates that several categories of users would interact with the recommended system. The purpose of the present section is to outline the major functions to be performed by each category of user. The list of functions is not complete for any category, but it characterizes the functions that should be supported by simulator control consoles. The number of people in each category cannot be specified at present, but would depend on research requirements and resource limitations.

Exercise Designers

Simulation exercises, whether for research or for training, may be divided conceptually into four phases: exercise design, compilation, execution, and analysis. Exercise designers focus primarily on the first two phases. Exercise design involves defining research variables or training objectives, specifying the exercise scenario and procedures, and developing or selecting performance measures. The compilation phase includes defining and entering modifications to the simulation data base and algorithm base, preparing graphics, and modifying performance measurement routines. A large portion of this work would probably involve the manipulation of alphanumeric information in tabular form. Following exercises, the designers would receive feedback in the form of reports prepared by the research staff.

Exercise Controllers

The two major categories of exercise controllers are computer operators and researchers. Computer operators would be responsible for the details of loading, compiling, and executing simulation exercises, and they would monitor the system for problems during an exercise.

A researcher's primary responsibility during a session will be to monitor operator/team performance. Rather than requiring the researcher to look over the shoulders of the operator, the researcher should have the capability of repeating operator imagery on his or her own console display. This visual information, coupled with voice information over an intercom, would enable the researcher to monitor performance during a session. In

addition, graphic displays should be developed especially for the purpose of summarizing operator performance. In a 1 v 1 intercept simulation, for example, the researcher should be able to call for a trace of the target and interceptor flight paths, along with a tabular summary of the amount of time and fuel consumed and any unsafe conditions that occurred. It should also be possible to direct this type of display to the operator's console for feedback. A complete definition of required graphics aids for performance assessment and feedback will depend on specific research and training requirements.

In addition to monitoring operator performance, researchers should be able to perform umpire functions such as controlling the rate of simulation events.

Following a session the researchers will need a detailed listing of performance data and statistical analyses of aggregated data. Performance data should be available in both tabular and graphics form. Computer technology makes possible the generation of vast quantities of data--the researcher/instructor will be responsible for defining performance data needs judiciously.

Script Readers and Role Players

Script readers and role players play the part of personnel who are external to the AFC^2 team being tested. Examples of typical roles are:

- Interceptor pilots and other air crews

- Blue (own force) subordinate or superior command staff members
- Red (enemy force) command staff

In the case of the first two roles, script readers and role players would provide the voice input to the AFC^2 team as determined by exercise events and research purposes. In the third role, role players would not interact verbally with the AFC^2 team, but would control simulation events as necessary to achieve research objectives.

A script reader's primary responsibilities during an exercise are to watch a clock and read items from a prepared script at specified times. Some interaction with AFC^2 team members may be required. For example, a script reader may call the team, wait for acknowledgment, and then continue with the script. Script readers currently read prepared text from formally prepared notebooks.

Scripts could also be presented on the console display, and the reader would read them as they appeared. This approach would have the advantages of ensuring synchrony between the script and simulated events and facilitating the maintenance and updating of scripts.

In some cases script reader functions could be automated. This would be possible if advanced voice synthesis capabilities were included in the simulation. Script items would then be triggered automatically by the clock or by simulation events.

A role player's functions are to monitor exercise events, provide verbal inputs to the AFC^2 team when appropriate, and interact with team members as necessary. A simple form of role playing in current simulations is illustrated by T-4 drivers, who control simulated aircraft on the basis of instructions from students and instructors. T-4 drivers must also respond by voice in the same way pilots would.

More sophisticated role playing would be required in some research applications. Role players could depict the command headquarters in charge of the experimental AFC^2 team, for example. In this case, intercom connections between the role players and the AFC^2 team would simulate radio-telephone links. Another major role would be the enemy command center. In this case, role players would function as adversaries against the C^2 team. Voice links between the two teams would not be appropriate in this situation. Instead, the Red (enemy) team would initiate certain tactical movements, which the Blue (own) team would detect on their display screens and counter with available simulated resources.

Script readers and role players could be in-house, contractor, or military personnel.

AFC^2 Team Members

The AFC^2 team members would be the experimental subjects for the empirical AFC^2T^2 research program. They would typically be military personnel familiar with AFC^2 operations. The necessary rank and level of experience of the team members would vary depending on research requirements and resource constraints.

Software Developers

Software developers would be responsible for designing, coding, testing, and debugging the software modules comprising the simulation system. They would coordinate with exercise designers to provide the required capabilities for each exercise, and with the researchers to develop the appropriate interface features and performance assessment routines. In-house and contractor personnel would serve as software developers.

Maintenance Personnel

Maintenance personnel would be responsible for the integrity of the hardware and software systems. Software maintenance functions could be performed by software developers, and hardware maintenance could be performed by vendor personnel or, if preferred, by in-house technicians.

SOFTWARE

Figure 6 illustrates the major software modules that are needed for the recommended research facility. The following paragraphs discuss the functional capabilities required for each module. The discussion is at a high level, and is intended to outline the issues to be considered in subsequent detailed analyses.

Operating System

The details of the operating system are relatively unimportant at the present high level of discussion except that the system should facilitate the jobs of the computer operators and the software development and maintenance personnel. Features that would be desirable are a powerful command language, access to high-level languages that are particularly well-suited to real-time processing and graphic displays, a convenient editing system, and sophisticated file handling and data base management capabilities.

Personnel Support Modules

Personnel support modules would control the displays and interpret the commands of all users of the system. Much attention has historically been given to the design of displays and control functions for operators--AFC^2 team members, for example--but very little effort has been directed toward defining operator-system interface features for exercise controllers and other system users. We recommend that the interfaces for all users be carefully engineered to maximize the utility of the system.

Software support for exercise controllers, particularly researchers, would be especially important because these people would be unlikely to be computer professionals, and they would be required to perform accurately within the time constraints of the exercise. Software support functions that would be most desirable are the following:

- Convenient display, entry, and modification of the contents of the simulation data base. Tabular displays of the data should be formatted to facilitate reading. Data entry and modification procedures should be designed to prevent errors and preclude the inadvertent loss of data.

- Graphics entry and modification procedures should be as streamlined as possible.

- An interactive dialog system should be developed to aid the exercise controller. A combined menu selection and function key system with extensive prompting of the user is recommended.

- Exercise controllers should be able to display on their own consoles a copy of the imagery on the console of any AFC^2 team member in order to monitor the activity of individuals.

- Performance assessment routines should be developed to permit on-line monitoring of team and individual performance during exercises. Exercise controllers should be able to specify key conditions and be notified automatically when the conditions occur.

- Designing and running data analysis routines should be convenient, and the output of such analyses should be formatted to facilitate interpretation. Graphic output of performance analyses should be possible.

This is a partial list of functions that should be performed by personnel support modules. The list should be expanded on the basis of a detailed analysis of the functions of exercise controllers. Comparable analyses should be performed for the other personnel categories listed in Figure 5.

Simulation Models

Simulation models should be developed for the following elements of the C^2 environment:

- C^2 communication network
- Superteam and subteam elements
- Own aircrews
- Aerial combat tactics
- Air weapons
- Sensor systems
- Communications and radar countermeasures
- Tactical situation

The functions of these models are described below.

C^2 Communication Network Models--The system should be capable of simulating a variety of C^2 voice communications networks. A fundamental network could include a single weapons director and an individual pilot, for example. An expanded network would include an entire weapons team and controlled aircrews. The communication network data base should

allow the researcher to specify the number of nodes in the network and the routes between nodes. In addition to the actual members of the AFC^2 team, the communication networks should include exercise control personnel, script readers, and role players.

The network models should interact with the communication control panel so that communication can be controlled by the panel. The amount of control allocated to the operator would be determined by the researcher. The models should be capable of replicating the volume of voice traffic that can realistically be anticipated on each voice channel.

Superteam and Subteam Element Models--These models are closely related to the communication network models in that the relevant set of AFC^2 team participants should be specified for each exercise, and communication among all team members should be feasible. It should be possible to define the experimental (or training) team on any of several levels, and it should then be possible to model the necessary subteam and superteam elements. Two examples illustrate this point.

If the experimental team had an AWACS-like structure, it would include weapons, surveillance, battle staff, and system support subteams. The team would exist in a larger command structure that would include a TACC, perhaps, and several aircrews. The TACC staff and aircrews would comprise the supterteam, of which the experimental team is a part.

As a second example, the experimental team of interest could consist only of a weapons section. The superteam at this level would consist of the other collateral sections, as well as aircrews and superordinate command groups.

Regardless of the level of analysis, the superteam members should generate inputs to, and respond to outputs from, the experimental team. The inputs and responses can arise from two sources: personnel and software. Script readers would provide voice inputs in situations that are relatively constrained. Role players would generate voice inputs in situations that are less constrained, and they would also manipulate simulation events in response to the actions of the experimental team.

It may be possible to develop software to automate the functions of some script readers and role players if state-of-the-art automatic voice recognition and synthesis capabilities are exploited. The superteam members that can be automated most feasibly are the aircrews because their legal vocabulary and range of response are extremely constrained. Because it is unlikely that the processing performed by a superordinate command staff could be adequately modeled soon, such functions would probably need to be performed by skilled role players.

Own-Aircrew Models--The possibility of automating own-aircrew functions in the simulator requires further elaboration. Two separate problems need to be solved before this approach will be feasible: interface processing and performance modeling. Interface processing involves the ability of the system to recognize voice inputs from experimental team members. The recognition error rate for the system should match

the typical rate for human role players. If this hurdle can be passed, other interface problems are also likely to be resolvable and certain advantages can be realized.

One advantage is that fewer people would be required for controlling exercise. In addition, if initial recognition performance is good, it should be possible to degrade recognition performance systematically. This would permit the empirical evaluation of the effects of communications jamming on AFC^2 team and system performance, for example.

Adequate aircrew performance modeling would enable researchers to define and manipulate various parameters of aircrew performance. One such parameter could be the lag between receiving a direction and actually initiating a maneuver. Another could be the characteristics of the maneuver: one simulated pilot could pull 1g when turning to a new heading, whereas another would pull 2g. This variance could be manipulated systematically to expose the C^2 team to a range of conditions.

The output side of the aircrew model also offers advantages over human role players. Skilled T-4 drivers can develop two or three voices, so that each pilot will sound different to the controller. Most T-4 drivers, however, use the same voice for all roles. Automatic voice synthesis routines could be developed to generate a unique sound for each simulated pilot. The emotional inflections and nonstandard or nonsensical utterances of pilots under stress may be difficult to simulate, but this problem is not unique to automatic voice synthesis: Human role players also have difficulty simulating such dialog.

Aerial Combat Tactics Models--In a standard intercept situation the weapons director guides the interceptor pilot toward the target until the pilot can acquire it directly, either visually or electronically. This basic situation can be elaborated on by increasing the number of intercept and target aircraft involved, and by simulating realistic aerial combat maneuvers. Knowledge of both friendly and enemy aerial combat tactics can be embodied either in role players or in simulation software. Both Red and Blue tactics should be included. The target should perform realistic evasive maneuvers.

Role players can handle relatively simple situations, but many-vs-many encounters, such as would be encountered in high-intensity scenarios, probably require automated assistance. Software-controlled simulated aerial engagements would generate a realistic "fur ball" on the display, and would enable the evaluation of the ability of the C^2 team to identify and recover friendly aircraft following mass air battles. Even in low-intensity situations, automated tactics would reduce the workload of simulator control personnel by controlling all combat maneuvers for intercepters and targets following a "Judy."

In addition to air-to-air combat models, air-to-ground missions should also be modeled so that close-air support (CAS) and strike control and armed reconnaissance (SCAR) missions may be exercised. In this way teams such as the Tactical Air Control Party (TACP) and Forward Air Control Post (FACP) could be observed or trained. The algorithms for air-to-ground combat would be similar to air-to-air models except that

the velocities of the targets would be lower than airborne targets (zero in the case of fixed installations) and altitude above ground level would be zero.

Air Weapons Model--The simulator should include current models of airborne weapons platforms, munitions capabilities, and ground-based air defense weapons. Platform models should include parameters for velocity, acceleration, turn rate, climb rate, fuel capacity, fuel consumption rate, and any other flight dynamics characteristics that are judged to be relevant. Airborne sensor system capabilities (visual or electronic) should also be modeled. These capabilities would be represented by parameters for probability of detection as a function of range, heading, target size, and environmental conditions. All aircraft could be characterized by the same set of parameters, and the researcher would define the particular mix and capabilities of aircraft appearing during the exercise by entering the appropriate parameter values into the simulation data base. If an exercise involved intercept runs against high-performance aircraft, high maneuver rates would be entered; if bomber intercepts were being practiced, the data base would contain high maneuver rates for the interceptors and low rates for the bombers.

Airborne munitions capabilities need to be simulated for the purpose of scoring kills during a simulated engagement. Details about the velocity, range, and lethal areas of munitions would not necessarily need to be included in the simulation, but this information should feed into analyses of kill probabilities as a function of heading, range, relative velocity, and the ECM/ECCM environment, and the probability functions should be included in the software. Targets that are destroyed should be automatically removed from the displays.

Sensor System Models--The simulator should include versatile models of primary sensor systems. The simulator would of course "know" the true position of all aircraft in the scenario, and exercise controllers should be able to view such ground and air truth information when required. Radar models, however, should degrade detection, discrimination, and location performance as a function of range, radar parameters, target reflectance, and ECM/ECCM conditions. The values for all parameters should form a part of the simulation data base.

Sensor models should respond in realistic ways to ECM disruption and other environmental factors. Further, radar input countermeasures operators (RICMO) should be able to adjust radar parameters (frequency, mode, etc) to counteract the interference. The imagery should change as a function of RICMO inputs. This type of versatility is not currently implemented in AWACS or CRC/CRP training systems although the need for it is recognized by the users.

Communications and Radar Countermeasures Models--Communications and radar countermeasures effects should be modeled. The simulator should be able to replicate various levels and types of voice communication jamming. When simulated aircraft are jammed, the pilot's response (either simulated or depicted by role players) should indicate communication difficulties. When the AFC^2 team is jammed, the headphones should carry acoustic noise in addition to the actual message. The characteristics of the noise should match the characteristics of typical communications jamming devices. Radar countermeasures models should generate display characteristics that accurately depict the effects of chaff distribution, jamming, and other ECM techniques.

Countermeasures models should be interactive in the sense that exercise controllers can invoke them as needed during an exercise. This capability would be required in order to evaluate team, particularly RICMO subteam, response to interference. It should also be possible to call countermeasures models automatically, according to a predetermined schedule or in response to predefined events.

Tactical Situation Models--The software models in this category comprise what may be termed the "driver scenario" for simulation exercises. The researcher would create scenarios for specific purposes by defining the set of Red and Blue resources to be included, their geographical distribution and objectives, and relevant environmental conditions. Blue and Red force resources data would include such things as the number of aircraft, armaments for each class of aircraft, and ground-based air defense weapons. The data bases for the aircrew, aerial combat tactics, and air weapons models would need to be entered or modified to meet the research or training requirements of the exercise.

The simulator should include models for air defense weapons for both Blue and Red forces. Each air defense site should be defined in terms of the firing rate, ammunition supply, and kill probabilities as a function of target range, altitude, and performance characteristics.

The researcher should be able to define the geographical distribution of Red and Blue forces. The geographical array should be completely flexible so that fictional areas can be simulated for some applications; whereas specific regions of the world can be simulated for other applications.

It should be possible to define the objectives of the Blue and Red forces. Objectives would typically be defined in terms of paths to targets from the initial staging areas, and return paths from the target to recovery fields. Red forces in most cases would be programmed to attack or defend certain areas, and interactive control of Red movements would be necessary only in selected exercises. Blue forces, on the other hand, would be under the control of the C^2 team. Blue movements would proceed according to the commands of the team members, who would be attempting to meet the objectives of the exercise. In some cases it would probably be necessary for the Red forces to be under the control of simulation control personnel, who would be playing the role of the Red battle staff. In these cases it should be possible to hold two-sided, free-play war gaming exercises.

The tactical situation models should allow the researcher to specify certain relevant environmental conditions: weather, day/night operations, ECM/ECCM environment, and so forth. Selection of a set of environmental parameters should determine which subsets of the data bases for many of the other software models would be relevant, and it should cause appropriate correction factors to be used as necessary. For example, the visual target detection range should be different for night operations than for day operations.

Tactical situation models would be the driver scenario in the sense that they would drive the movements and behavior of Red and Blue forces according to a plan. The plan would be predetermined by the researcher/ instructor, but it should unfold according to the actions of the AFC^2 team. Mistakes by the team should be followed by realistic Red gains and Blue

losses; excellent C^2 team performance should be followed by events that are more advantageous to the Blue forces. Whatever the outcome, the driver scenario should be tied to the display control software module so that imagery realistically depicting the simulated events would appear on the operator displays.

Simulation Data Base and Algorithm Base

Each of the models described above should be developed in the form of generalized parameters that can be set in any of a range of values. The specific values for a particular application should be stored in a data base that could be readily accessed by exercise design and control personnel. In addition to the data base, the models should also access a modular algorithm base that includes the subroutines required for performing specialized functions. It should be possible for software developers to refine the algorithm base by modifying or replacing selected algorithms as necessary to meet research requirements.

Applications Programs

Software development personnel should have the capability to prepare and use special-purpose applications programs as the need arises.

CHAPTER III

POTENTIAL IMPACT OF ADVANCED SIMULATION TECHNOLOGY ON AFC^2T^2 PROGRAMS

The state of the art in simulation technology provides the capability for dramatically improving the cost-effectiveness of AFC^2T^2 programs. The improvements can be achieved through:

- Presenting a wider range of training problems
- Achieving greater tactical realism
- Increasing the amount and quality of student practice time
- Improving the efficiency of live exercises
- Making improved use of instructor time and talents
- Setting higher standards of proficiency

The following sections outline these benefits in more detail.

WIDER RANGE OF TRAINING PROBLEMS

AFC^2 teams must deal quickly and effectively with a variety of complex tactical problems. A flexible simulation system would enable instructors to expose C^2 teams to a wider range of conditions than is possible with current simulators. The payoff for this flexibility would be C^2 teams which are prepared to react and adapt to unanticipated contingencies in the operational environment.

Current C^2 simulators do not have the flexibility that is required to generate a broad range of combat conditions. T-2 exercises on the TSQ-91 (CRC), for example, require complex development procedures that are not generally available to instructional personnel. The T-4 system adds capabilities that alleviate some of the problems with the T-2, but it is severely limited in terms of the number and types of aircraft tracks that it can generate. Furthermore, details of the architecture make even minor modifications in its performance characteristics prohibitively difficult. Numerous exercises combining T-2 and T-4 capabilities have been developed but they are extremely difficult to modify. As a result, the exercises present only a relatively small sample of the tactical problems to be faced by operational C^2 teams, they tend to be outdated, and they lack the flexibility to be revised by instructional personnel.

The AWACS simulator is newer and considerably more capable than the T-2 and T-4 devices. Moreover, it is supported by System Exercise Problem Packages (SEPPs). SEPPs are computer-driven tactical exercises intended to provide experience for C^2 teams in performing tactical operations at graded levels of intensity in a variety of geographical areas. The SEPPs are potentially much more valuable than T-2 or T-4 exercises in exercising a broad range of training problems, but they are difficult to use and cannot be readily updated by instructional personnel who are not software professionals. SEPPs consequently tend to be underused and do not actually provide the broad range of problems that they were intended to.

GREATER TACTICAL REALISM

AFC^2 teams will be more likely to be able to perform effectively in actual operational settings if simulation exercises present realistic combat contingencies. The AFC^2 systems we surveyed do not represent mid- or high-intensity engagements based on realistic numbers, densities, distribution, capabilities, and tactics of own and threat forces. Moreover, it is difficult to modify the models and data base to permit the simulation of various levels of intensity, force ratios, and weapons mixes. Simulation capabilities such as those outlined in Chapter II are required for this type of realism and flexibility.

INCREASED AMOUNT AND QUALITY OF STUDENT PRACTICE TIME

Advanced simulation technology can potentially provide additional capabilities for students to practice control and surveillance techniques privately, without requiring instructor or staff participation. A student weapons controller, for example, could log on to a simulation console, select an exercise or ask the system to select one appropriate to his skill level, and run it. Such exercises would require the display, scenario, and automatic voice recognition/synthesis capabilities described in Chapter II.

The approach outlined above is a form of computer-based training (CBT). It shares with other computer-based techniques the advantages of enhancing student motivation by allowing private, self-paced instruction that can be adapted to the student's performance level, given performance measurement techniques and optimization routines. Moreover, in contrast to

traditional read-and-respond approaches to computer-assisted instruction (CAI) that require verbal/typed responses, the recommended approach emphasizes dynamic free-play and task-oriented responses.

The individualized CBT exercises would not necessarily replace or even reduce the amount of time students spend in contact with instructors or in team exercises. Instead, the purpose is to increase the quality of instructor interaction and team exercises. This would occur because the instructor would be freer to deal with substantive issues raised by students on the basis of the simulation experience. Team exercises could also potentially be enhanced because team members individually could enter the exercises at a higher level of proficiency than is currently possible

The CBT approach could operate in the manner of a CAI study carrel system in a learning center. It would be most appropriate for initial training and initial transition training of individual skills for all personnel categories shown in Figure 1. It could also be used for advanced training and perhaps for subteam training, although such applications would be more difficult. Individualized instruction in learning centers is well accepted and effectively used at many of the sites we visited--provided that instructors and students perceive that the instructional material is valid and useful. The CBT approach would therefore be consistent with current AFC^2 training practice.

IMPROVED EFFICIENCY OF LIVE EXERCISES

Live exercises are too costly to use in providing training that can be delivered as effectively or more effectively in simulation exercises.

Consider the example of a student weapons director who is learning to control live intercepts. A partial list of participants includes:

- The student
- Another student who is playing the role of weapons technician
- An instructor who is overseeing the entire exercise
- Aircrews for the interceptor and target aircraft
- Air traffic control and aircraft maintenance personnel

Such exercises entail a very real risk of injury and property damage, and require hours of planning, attending pre- and post-mission briefings, and the consumption of jet fuel and flight resources. The payoff may be only a few minutes of time on the scope actually controlling aircraft, time which may be cut short because of weather or mechanical problems. AWACS exercises are considerably more expensive because the students are themselves airborne, which requires a complete flight crew, jet fuel, and ground air traffic control, logistics, and maintenance support. Large-scale multisite C^2 exercises are tremendously more expensive than the examples cited above because large numbers of aircraft, ground facilities, and personnel are required.

Given the cost of such exercises, it is unfortunate that participants use a major portion of the exercise time learning basic functions that could be exercised if simulation capabilities such as those described in Chapter II were available. In this case a larger proportion of live exercise time could be spent developing the team and superteam coordination skills that cannot feasibly be developed in simulation exercises.

IMPROVED USE OF INSTRUCTOR TIME AND TALENTS

It is possible within the current state of the art to free instructors from the more routine duties of monitoring and evaluating student performance. Instructors could then devote time to other activities such as planning, tutoring, and diagnosis, which are more appropriate channels for their skills and knowledge. Volume I, Chapter II, identifies instructional support features that should be incorporated into the design of training simulators.

For convenience, the list is repeated below:

- Automated assessment and monitoring of operator and team performance
- Presentation of performance data to instructors
- Automated branching among lesson segments on the basis of student or team performance
- Automated delivery of feedback and prompting to students and teams
- Capability for simulating events in real time and at rates other than real time
- Capability for replaying simulated events
- Part-task training capabilities--the ability to exercise a subset of the operator's or team's duties
- Capability for presenting successive approximations to the quality and appearance of imagery on a display scope

- Flexibility, ease of maintenance, and convenient modifiability so that instructors who are not computer professionals can make necessary changes in the data base and models driving exercise scenarios

The design outlined in Chapter II of the present volume provides for the definition and development of these features. The first four features depend on the development of operator and team performance measurement techniques, which is a major research issue in itself.

These features would increase training efficiency by reducing the amount of instructor time required for each hour of student time. The ability of the training device to monitor and evaluate student performance, for example, would substantially reduce the requirement for instructor time. Current practice in Basic, APQ, and AWACS training is for an instructor to monitor one or two students as they are working on scopes. Such attention is appropriate in live exercises, in which safety is a paramount concern, but the instructors we interviewed felt their time would be better spent on other duties during most simulation training.

The automatic monitoring function could be designed to detect impending unsafe conditions, and it could also make qualitative assessments of operator and team performance. Software-induced alarms could then warn the instructor whenever operator or team performance falls below criterion or is about to become unsafe. This would free the instructor to be present for a particular student or team only when his presence is most important.

Another instructional support feature that would help relieve the instructor from some of his present duties would be automated recordkeeping and lesson control. The instructional staff could then set criteria for each unit of instructional material. As operators or teams met the criteria, they would be branched to the next unit. Failure to meet criteria would flag the instructor or branch the operator or team back for remediation. The student records generated in this process could be made available to instructors in summary form or in as much detail as desired.

The ability of the training device to monitor student performance and maintain performance records would permit instructors to focus their attention on instructional planning and on specialized interaction with students. These benefits would permit a greater flow through the training pipeline without a corresponding increase in the required number of instructors. This consideration is most important in academic, school settings in which large numbers of students are involved. Small on-the-job training (OJT) programs would also benefit from these capabilities because of their limited instructor resources. In either case, initial training or in-unit OJT, the recommended instructional support features would enable a given instructional staff to deliver more training than is currently possible.

The instructional support functions discussed above, particularly automatic performance assessment, are technically difficult. One major function of the recommended AFC^2T^2 research facility should be to explore their feasibility.

HIGHER PROFICIENCY STANDARDS

Training developers, managers, and instructors at all sites we visited expressed a common concern: the skill and knowledge level of entrants into the 17xx career field has apparently been dropping over the past several years and is continuing to drop. The required number of 17xx personnel has not decreased, however. This has forced schools to reduce performance requirements for graduation. Courses that may once have required proficiency in 4 v 2 intercepts (four interceptors vs two hostile aircraft) for example, may only require 2 v 1 proficiency now. This reduction in training standards has a ripple effect throughout the training pipeline. As one means of reducing or reversing this decline, many of the experts we interviewed recommended establishing screening tests and other measures to increase the entry level of new personnel.

Another approach would be to modify the training programs to meet the requirements of the new personnel. This would be a major undertaking requiring substantial personnel resources, time, and facilities, but advanced simulation technology offers the potential for aiding in this process.

If advanced simulation technology achieves the potential benefits outlined in the present chapter, it may play a direct role in increasing the proportion of students who meet or exceed course criteria. The ability to practice on a wider range of tactically realistic exercise problems than is currently possible can improve the performance capabilities of students and teams. The increased motivation and confidence derived from these exercises in conjunction with advanced CAI techniques can

enhance the benefits of live exercises. Instructional support features of advanced simulators can potentially improve the level and quality of instructor interaction with C^2 students and teams. All of these factors working together can potentially allow training standards to be raised from present levels to meet the actual requirements of the operational environment. If this potential is realized, advanced training simulation technology will have made a substantial contribution to the readiness of tactical AFC^2 systems and teams.

CHAPTER IV

TECHNICAL FEASIBILITY OF THE RECOMMENDED AFC^2T^2 RESEARCH FACILITY

The present chapter provides an initial assessment of the technical feasibility of the major features of the recommended AFC^2T^2 research facility. Because the system is a many-faceted device, the feasibility of building it cannot be described with a unitary measure. Many of its features are feasible given current simulation technology. Others will require significant advances in the state of the art. The first two sections of this chapter discuss the feasibility and risk of the hardware and software features of the design. Feasibility and risk are assessed in a relatively subjective fashion based on professional judgment and experience. In order to provide a more substantive basis on which to judge the feasibility of the recommendations, the third section describes a set of simulation systems that, taken together, combine many of the features of the recommended research facility, although no single system currently embodies the entire set of capabilities.

FEASIBILITY OF HARDWARE FEATURES

The hardware comprising the recommended research facility consists of the following functional units:

- Console equipment

  --Displays

- --Keyboards (function and alphanumeric)
- --Track ball
- --Communication gear

- Processing equipment
- Automatic voice recognition and synthesis equipment
- Large-screen displays
- Other peripheral units
  - --Printer
  - --Digitizer and map bug
  - --Mass storage devices

The greatest hardware risk lies in the areas of voice recognition and synthesis. Accurate and reliable voice recognition devices have been developed and are commercially available at modest cost. The systems are currently able to recognize only isolated words, but most are unable to parse utterances into multiword strings. Careful analysis is required in order to determine whether this limitation is critical. It is possible that brevity codes are such that an isolated word recognizer could function adequately in models of interceptor pilots, even without sophisticated parsing capabilities. Such capabilities would be mandatory if command staff and other complex superteam elements were to be automated.

Much less risk is associated with automatic voice synthesis. Implementation options range from true synthesis, on one end of the continuum, to random access to prerecorded utterances (on tape or audio disks) on the other. The simulation needs the capability to generate a unique voice for

each simulated pilot or user the C^2 team interacts with. It would also be valuable to develop a model that would cause the intonation and inflection of the synthesized voice to change as a function of situational variables that normally affect aircrew stress and workload, although such modeling would be difficult technically.

Role players and script readers serve the functions of voice recognizers and synthesizers in current simulators. Cost-benefit analyses are required to determine the actual value of automating these functions. An important consideration in this analysis is that a potentially large number of role players will be required if scenarios calling for realistic air traffic densities are developed. In addition, reliability and repeatability, which are important considerations for a research device, are likely to be greater for an automated system. For these reasons we recommend using automatic voice recognition/synthesis capabilities in selected, well defined domains.

Except for voice recognition/synthesis, the level of technical risk associated with each unit is low. All units are available commercially and may be procured without modification. The technical difficulty in building the simulator lies almost exclusively in software development.

FEASIBILITY OF SOFTWARE FEATURES

Figure 6 illustrates six major software modules that are required for the recommended AFC^2T^2 research facility:

- Operating system
- Personnel support modules
- Simulation models
- Simulation data base
- Algorithm base
- Applications programs

Of these, the only modules that entail substantial technical risk are the personnel support modules (particularly for the exercise controllers and AFC^2 team members) and the simulation models. The feasibility of these modules is addressed in the following pages. In addition, two approaches to the representation of teams and team tasks are also discussed because of the central importance of this problem to the development of successful software.

Software to Support Functions of AFC^2 Team Members

The personnel support modules for AFC^2 team members should be able to perform the following functions:

- Display visual imagery
- Interpret operator inputs
- Provide feedback
- Transfer data among communication nodes

The first function is straightforward, although generating the events to be displayed is a nontrivial problem (see the discussion of tactical situation models below). The second function is also relatively simple for key press and track ball entries. The process of interpreting voice inputs (automatic voice recognition) involves some technical risk, although recent technological advances have reduced the risk.

The problem of providing feedback to students is relatively simple, given that the performance measurement problem has already been solved.

Selecting lesson material, evaluating performance, and providing feedback are more difficult in the team context than they are for individual training or research. The technical difficulty of these functions stems primarily from the difficulty of developing the conceptual methodology. Software implementation of the solutions is probably within the current state of the art.

The process of transferring data among simulation elements is not a difficult software problem. This capability will be required for simulation control, evaluation of performance data, and communication among exercise participants.

The difficulty of software development probably does not vary significantly as a function of operator type (weapons, surveillance, battle staff, etc).

Software to Support Functions of Exercise Controllers

The personnel support modules for exercise controllers, particularly researchers, should be able to support the following functions:

- Display visual information
- Interpret inputs from exercise controllers
- Cue exercise controllers when specified conditions or events occur
- Reduce and process performance data
- Select lesson material
- Transfer data among communication nodes

The first two functions and the last one are similar to functions for AFC^2 team members and carry the same low risk. The difficulty involved with these functions is related to the problem of defining exactly what the exercise controller should see on the display, and what functions are required to support exercise controllers.

The ability of the system to recognize specified conditions and events is important. The exercise controller should be able to define the conditions under which he or she wishes to be alerted. One condition could be when an AFC^2 team violates a safety rule, for example. Another could be successful completion of a mission by a team. In the first case the exercise controller could provide corrective feedback; in the second case he or she could give positive feedback. This capability would permit the exercise controller to focus on other events and activities--the filtering process would be performed by the software. The analysis required for

implementing this function would be complex, but the software requirements for implementing the solution are well within the state of the art.

One of the most important software functions in support of the exercise controller would be the automatic processing and presentation of individual and team performance data following an exercise. The technical difficulty in this area concerns the definition of just what information should be presented and how it should be formatted. A common problem with data processing systems is that they can easily overload a user with uncorrelated information. The technical challenge (and risk) lies in performing analyses that will measure what is useful, rather than what is available. These analyses are closely related to the general problem of developing reasonable performance measures, individual and team, for operators in C^2 systems.

The fifth function, the automatic selection of lesson material, would be important in research investigating various branching and presentation strategies for computer-assisted training programs. The capability to select lesson material would give a training device much of the power and flexibility normally associated with CAI.

The primary advantage is that the training could be adaptive--the content and difficulty of the lesson material could be adapted to the abilities of each individual student. Students and teams could be brought to criterion at different rates and along individualized routes. Adaptive training depends on the ability of the system to evaluate student performance.

The major technical problem in this area concerns performance assessment *per se*. It is difficult in many situations, especially in emergent situations, to identify and quantify relevant, valid, and reliable performance continua, and to establish criteria for acceptable performance. Once this step has been taken, the software development required for implementing the solution should not be overly complex. The complexity of various solutions cannot be assessed in advance, however, but must be evaluated on a case-by-case basis.

Software for Simulation Models

Figure 6 lists several classes of simulation models comprising the driver scenario for research exercises. The function of these models is to generate the events and contingencies within an exercise. The following paragraphs discuss the feasibility of each major type of model.

Voice Communication Network Models--The definition of which participants can be called from a given console must be under software control because it will vary widely from one research/training application to another. A system should be developed so that simulation control personnel can change the definition conveniently whenever necessary. The nodes in the net should include all participants in the exercise, as well as the automatic voice recognition/synthesis modules. The technical difficulty of developing software required for implementing these functions is relatively low.

Superteam and Subteam Element Models--Superteam elements must be modeled whenever members of the C^2 team interact with elements outside the team. One superteam member is the interceptor pilot. Modeling the

pilot appears to be within the state of the art, and such a model could include automatic voice recognition/synthesis if isolated word recognition capability proves adequate. A requirement for the speech recognizer to parse multiword utterances would increase the technical risk. More complex superteam elements such as superordinate command organizations would be much more difficult to model. The primary difficulty would be in defining superteam and subteam elements, the parts they play in an exercise, and the functions needed to execute these roles. In the meantime, role players and script readers offer a more tractable alternative.

Own-Aircrew, Air Weapons, and Sensor System Models--This set of models should be constructed so that the parameter values can be modified readily. Examples of parameters that should be modified are latency, accuracy, and response patterns of simulated pilots, aircraft performance parameters, aerial munitions parameters, and sensor system and communication system capabilities. The process that is required for determining the appropriate parameter values is laborious, but the technique of designing a model so that parameter values can be modified when necessary is standard programming practice.

Aerial Combat Tactics Models--The complexity of simulating aircraft movements during aerial combat varies with the number of aircraft being simulated, and complexity increases more rapidly than the number of aircraft. For this reason, algorithms for simplifying this type of model need to be developed before large-scale engagements can be adequately simulated. It is within the current state of the art to simulate small scale engagements in detail. The dividing point between small- and large-scale conflicts may be determined on the basis of more complete analyses.

Electronic Countermeasures and Counter-Countermeasures Models-- Electronic countermeasures (ECM) and counter-countermeasures (ECCM) are important features of modern warfare. C^2 teams must be proficient in the detection and analysis of ECM that is being directed against them, and in the use of defensive ECCM techniques. Software capabilities that are required to simulate electronic warfare (EW) functions include:

- Displaying the effects of chaff distribution and other forms of active radar jamming
- Displaying the effects of ECCM actions taken by the C^2 team to counter radar jamming
- Presenting the effects of communications jamming of various types. The presentation would be in the form of acoustic noise played over the headphones of the C^2 team being jammed. In cases in which external elements such as intercepter pilots (simulated) are being jammed, the effect would be to reduce the probability that the pilots would respond correctly to inputs from the C^2 team; the pilot would either not respond at all or would say "Say again," for example.
- Responding realistically to ECCM steps taken to reduce the degree of communication jamming

Developing the models to implement these functions will require a major analysis effort on the part of EW, modeling, and cognitive research specialists to define the set of required capabilities and the appropriate level of fidelity. The ECM and ECCM modules would be valuable, in some cases essential, components of the system, but they will be difficult to develop.

Tactical Situation Models--The models controlling the tactical situation may be the most difficult to define and develop. The major software functions required for these models are:

- Accepting inputs from simulation control personnel regarding the initial conditions prior to an exercise. Initial conditions include the distribution and capabilities of Red and Blue forces, and the general plan of action.
- Following a preplanned schedule until it is modified by exercise participants.
- Receiving and responding to input from role players who are acting as Red and Blue commanders.
- Receiving and responding realistically to input from the operators/students who are the C^2 team.
- Developing and sending to the display processor information about the movement and disposition of all movers in the scenario in real time and at variable rates both faster and slower than real time.

The first difficulty with these functions is the analysis that is required to define the models in detail. Although the process of developing the models is relatively difficult, the technical risk is low because similar simulation and gaming capabilities have already been developed in other contexts (some notable precedents are discussed later in this chapter) and many of the pertinent data exist in current Air Force modeling and simulation systems.

A second major problem is to develop interactive software that will produce movements in real time and, when research or training requirements dictate, at rates other than real time. One approach that has been taken in the past is to develop movement frames in an off-line processing mode and then, during an exercise, presenting the frames at the required rate. This approach is appropriate for a variety of applications, and is in fact a computerized analog to the T^2 simulation system. The pre-canned movements approach is inadequate for applications that require simulated events to be responsive to operator/student or researcher/instructor inputs.

The complexity of interactive movement models varies with the number of movers being portrayed, and the number of movers to be portrayed depends on training and research requirements that need to be defined for each application. Preliminary estimates are that the number of target elements that need to be controlled interactively exceeds the capabilities of all current systems. The technical difficulty of developing tactical scenario models that meet research and training requirements is therefore relatively high. On the other hand, the difficulty of meeting an important subset of the requirements is low. The state of the art limits the complexity of scenarios that can currently be portrayed. Beyond that limit, advances in simulation technology will be required.

Software for Simulation of Tasks and Teams

Simulation of tasks and teams in man-machine operating systems requires the capability to represent them in software as networks. The representation has three aspects: 1) models for tasks and operators performing them,

2) combination of the task models into serio-parallel combinations corresponding to missions and multi-person groupings, and 3) sequential dependencies among tasks.

Two techniques have been developed to handle these representations: The Siegel-Wolf modeling and the SAINT (Systems Analysis of Integrated Networks Tasks) software language. Both have been used successfully in some situations. Although they are still in embryonic stages of development, they offer the potential for simulation of C^2 team tasks in tactical missions.

The Siegel-Wolf model has been applied to several problems in research on teams: Communication as an index of team behavior (Reference 1), one- and two-operator systems (References 2, 3, and 4), intermediate-size crews for aircraft (References 2 and 5), performance of submarine crews (Reference 6), and performance degradation of air crews as a result of radiation (Reference 7). The model has provision for workload and time stress (Reference 8).

SAINT is a software technique which extends the Siegel-Wolf approach. It has also been applied to C^2 team situations in AWACS (Reference 9) and Remotely-Piloted Vehicle operations (Reference 10). It has also been used in design research for the Digital Avionics Information System (Reference 11).

There appears to be no existing modeling approach which is adequate for simulation of C^2 teams. The evaluation of existing models was summarized by Pew, et al. (Reference 12) as follows:

> "...we believe that integrative models of human performance compatible with the requirements for representing command and control performance do not exist at the present time. What is available is a collection of bits and pieces taken from a variety of frameworks that might be drawn together to build an eclectic model for a particular task situation of interest. The assembly of the pieces will require substantial effort in and of itself and is likely to require many assumptions about particular aspects of performance. If one is to have confidence in the product so generated, several iterative validation steps at different levels of abstraction will be required."

However, the Siegel-Wolf and SAINT approaches are considered the most advanced techniques for representing networks of tasks and teams. They require development for applications to C^2 teams. Nevertheless, they provide a technological base and software framework on which to build.

The SAINT approach is the more promising. It is adaptable to different levels of specificity of the activities in tasks and a richness of performance measures. It was designed to provide terminology for representing multi-person configurations and interactions.

The evaluation of SAINT by Pew, et al. (Reference 12) is:

> "As a simulation utility that employs a bottom-up approach to performance prediction, SAINT is probably without peer at this time. It incorporates what we consider to be the most satisfactory concepts with respect to task and operator parameters identified in SWM, and employs a high level language that is easily learned and manipulated by the user. Further, the very flexible branching structure and the capability for changing the sequence of subsequent tasks offer what is perhaps a unique opportunity for the simulation of system missions with broad dynamic range."

We recommend an evaluation of SAINT for the purpose of describing teams and team activities.

MAJOR EXISTING MILITARY C^2T^2 SIMULATION FACILITIES

Many simulators have been developed to train individuals and teams to perform C^2 functions. Examples include the following:

- AWACS simulator
- TACFIRE Trainer Set (TTS)
- SOTAS Ground Station Simulator (SGSS)
- Combined Arms Tactical Training System (CATTS)
- Naval Warfare Gaming System (NWGS)

These systems do not exhaust the relevant examples but, taken together, they include most of the functions described for the prototype system outlined in Chapter II. Voice recognition and synthesis are the two notable exceptions, but these capabilities can be found in other systems (for example, the Navy's Precision Approach Radar Training System).

All five systems listed above were designed as training devices rather than as research facilities, although significant research has been performed on the TACFIRE Trainer Set, CATTS, and the SOTAS simulator. The NWGS is also intended to support research. The AWACS, TACFIRE, and SOTAS simulators provide individual and team training for operators of complex C^2 systems in the Air Force and the Army. The CATTS and NWGS facilities were designed to provide training in force management and tactical decision-making; equipment operation, per se, is not a primary concern. The AWACS and TTS trainers are equipped with operational equipment driven by simulation software. The other systems consist primarily of off-the-shelf equipment.

The following discussion presents a high-level overview of the functions and capabilities of each system listed above, and emphasizes the features that are most relevant in the present context. The theme of the discussion is that the technical risk associated with various features of the prototype is within reasonable bounds if similar features have been implemented in existing systems.

AWACS Simulator

The hardware comprising the AWACS simulator, at Tinker AFB, is quite similar to that proposed in Chapter II for the AFC^2T^2 research facility. The simulator includes nine student stations and several other support stations. The student stations are actual operational situation displays driven by simulation software. As in the operational system, the student consoles can be reconfigured to support battle staff, weapons, or surveillance functions. The support stations include a Computer and Display Maintenance Operator (CDMO) console and, in an adjacent room, simulation control consoles. The CDMO station functions primarily as a simulation control station, and is not typically involved in actual exercises.

Operator consoles include displays, function keys and switches, an alphanumeric keyboard, track ball, and communication gear. The physical fidelity of the consoles is high because operational gear is used.

The AWACS simulator hardware does not include large-screen displays or automatic voice recognition/synthesis capabilities.

The software driving the AWACS simulator performs many of the functions recommended for the prototype research/training simulator. Visual imagery comparable to real-world imagery is displayed to the operators, and the function keys operate as they do in the actual system. The functional fidelity of actions is enforced by the fact that the simulator software is under the same strict configuration management system that controls the airborne software.

The careful control of the airborne software is understandable given the risks involved in actual operation. The unfortunate consequence of controlling the simulator software as closely is that it is apparently very difficult to implement changes that would improve the utility of the simulator as a training or research device. Needed changes or additions suggested by system users are listed below:

- Interceptor pilots should be simulated. Software to control the tracks and provide verbal responses and inputs for the AFC^2 team should be developed.
- Performance assessment routines should be automated. Instructors should not be restricted to looking over the shoulders of students and providing verbal guidance and feedback.
- Performance data should be collected during an exercise and printed out for the instructor at the end for post-mission evaluations.
- Superteam elements should be modeled.
- It should be more feasible to tie the simulator to other nodes in a C^2 network.
- The simulator should be responsive to ECM and ECCM inputs. Several respondents remarked during our interviews that such a capability would be valuable, especially for the surveillance subteam. They felt that it should be possible to introduce EW problems into an exercise and train the operators to deal with them. The simulator currently does not display such interference and does not respond when operators make corrective inputs.

Changes in radar mode, for example, do not change simulated imagery even though actual imagery would change.

SEPPs have been developed to provide exercises of various levels of difficulty in various parts of the world. A set of exercises exist for a Mid-East airspace, for example, and the exercises are graded to expose the students to a variety of situations at several levels of intensity. The SEPPs are good attempts to explore the AFC^2 problem space, but they have several major drawbacks:

- They are difficult to modify and are therefore typically outdated.
- The procedures for modifying a SEPP exercise require resources and expertise that are typically not available. This situation underscores the design criterion that the tactical situation models in the prototype research/training simulator should be readily modifiable by personnel who are not software professionals.
- The SEPP scenarios are not interactive to the extent recommended in Chapter II. The software actually stimulates the operating system to produce simulated air traffic returns. These returns are precanned and noninteractive, except that AFC^2 team members can attach track labels to the returns as they would in the operational system. Interactively controlled tracks can be overlaid or masked with this background. These tracks, which are similar to T-4 tracks, are controlled by exercise controllers and role players, and can be used for intercept exercises and bump-heads free-play, but they cannot currently be used to simulate larger-scale, two-sided, free-play engagements.

- All knowledge of aerial combat tactics resides in the exercise controllers and role players rather than the software.

<u>TACFIRE Trainer Set (TTS)</u>

The TTS, which is operated by the US Army Field Artillery School at Fort Sill, consists of over a dozen TACFIRE terminals driven by a TACFIRE computer. The terminals are artillery control consoles (ACCs) and/or variable-format message entry devices (VFMEDs). The precise number of each type of terminal is a variable that depends on training objectives and lesson plans.

The consoles consist of small CRT screens, function keys, and an alphanumeric keyboard. Only alphanumeric characters are presented on the displays; the terminals have no graphics capability. The TTS uses operational equipment, so physical fidelity is not an issue.

The TTS uses no large-screen displays, but it does incorporate a digital plotter map (a large X-Y plotter) that prints hard copies of geometrical information.

The TTS is not hampered by the software constraints discussed for the AWACS simulator. Rather, the operational software is flushed out completely and is replaced by lesson modules written in PLANIT (References 13 and 14). The lesson modules are written to make the system look to the operator as if he is interacting with the actual TACFIRE system. The advantage of using PLANIT is that operator performance can be monitored objectively, quantitatively, and accurately. Feedback

can be directed to the student whenever he makes an error or performs well. The operator can be branched to more complex material or looped back through remedial material, depending on his performance. PLANIT makes detailed performance records available to the researcher/instructor whenever requested. The type and amount of detail can be tailored to the requirements of specific research or training applications.

The Army Research Institute (ARI) has sponsored excellent work to test the utility of PLANIT for team training in the TACFIRE context (References 15 through 19). PLANIT essentially acts as a buffer between team members. PLANIT can check messages sent from one operator to another for accuracy before they are actually transmitted. Feedback can then be sent to the first operator as a corrected message is sent to the second. PLANIT can also monitor team processes and identify steps that are taking too long. Feedback can be issued directly to the operators and/or the instructor can be summoned for assistance. Such an approach could be followed in AFC^2T^2 research and training, although AFC^2 systems rely more on voice communication and less on digital messages than is the case in TACFIRE.

TACFIRE is well-suited to the frame-oriented CAI approach of PLANIT. PLANIT may also be appropriate for the AFC^2 research and training environment as well, although the fit may not be as close. The imagery requirements of AFC^2 displays may be difficult in PLANIT, but recent advances have improved the graphics capabilities of PLANIT.

The TTS is not particularly well-suited for war gaming exercises. Its focus is on providing basic skills training for TACFIRE operators and teams, and artillery tactics are taught elsewhere.

SOTAS Ground Station Simulator (SGSS)

The SGSS is designed to support training and human factors research for the engineering development model of the SOTAS. The SGSS is the latest in a series of SOTAS simulators designed and built by Honeywell's Systems and Research Center under contract to PM SOTAS.

The SGSS includes 10 operator consoles, three instructor control stations, and a bank of minicomputers with associated peripherals. The SGSS departs from the tradition of the AWACS and TTS simulators in that commercial, off-the-shelf equipment was used in its construction. It is driven by 20 minicomputers, two for each student console, rather than by a single mainframe computer. Among other advantages, this distributed processing approach reduces the probability that hardware problems will cause all consoles to fail simultaneously.

The use of commercial equipment reduced both the initial cost of the system and the lead time required to obtain major units. It also enabled system designers to tailor the hardware and software configuration to a training and research environment, as opposed to an operational field setting.

Each instructor control station includes a CRT screen, keyboard, and communication control panel that allow instructors to define lessons,

monitor student progress, and establish voice contact with specific students. In addition, an instructor can play the role of external superteam members.

Student consoles consist of imagery displays, function keys, an alphanumeric keyboard, track ball, radio, and intercom gear. As in the operational system, a console can be reconfigured to support any of the four major types of SOTAS ground station operators. The consoles are configured to look like operational equipment, and are installed in rooms that match the size and shape of the truck-mounted SOTAS vans.

The imagery for operator displays is generated off-line and is stored, frame by frame, for presentation during exercises. The scenario is precanned and noninteractive. The scenario includes only Red force elements. Blue force elements are not currently portrayed. Users can decide which portion of the material to view and can vary the viewing mode freely, so the system is interactive in that sense, but it does not support war gaming functions such as those recommended for the prototype research/training simulator.

Operator procedures (that is, key press sequences) are functionally equivalent in the operational system and the SGSS. The SGSS software was built with the flexibility to test alternative procedures, however, so the SGSS functions both as a trainer and as a human factors research tool. The flexibility inherent in the software design also permits the development of performance measurement routines and instructor aids.

Combined Arms Tactical Training System (CATTS)

CATTS is an impressive simulation facility that has been in use at Fort Leavenworth for approximately five years (References 20, 21, 22). The purpose of CATTS is to provide simulated combat experience for battalion command groups. The command group is situated in one of two environments, either the main command post (a simulated tent) or a tactical command post (a simulated armored personnel carrier). The command groups are equipped with communication equipment (radios and field telephones), maps, and grease pencils.

CATTS currently simulates battles in German and Mideast environments. Other geographical areas could also be simulated provided that the data were available and the analyses were performed. The principal data sets that change with location are intervisibility, movement rates, and Red and Blue force structures. Within a particular environment, CATTS is essentially a two-sided, free-play war gaming system in which the Blue forces are commanded by the battalion command group and the Red forces are commanded by the exercise controllers.

The physical fidelity of the equipment and surroundings is high. The main and tactical command posts actually look like the interior of a tent or armored personnel carrier. Standard tactical maps are used, and the shells of actual radio and telephone sets are tied into the computer and control rooms. Audio speakers present the sound of incoming and outgoing artillery fire, and the loudness and frequency of the concussions varies with the intensity of the battle and its distance from the command post.

Communications jamming is simulated by adding computer-generated noise to the voice signals going from the control center to the command group.

The communication equipment feeds into a control room that is staffed by simulation controllers who monitor Blue force movements and control Red force movements. The battalion command group is in control of several companies. All information about Red movements and the condition of Blue forces gets to the command group in the form of reports from the simulation controllers, who play the role of company commanders. The controllers move the Blue units as directed by the battalion commander but within the constraints of the scenario. They then move Red units to apply as much pressure on the Blue force as they feel is appropriate. The battalion command group is fighting an essentially omniscient enemy.

CATTS software and hardware do not drive operator displays or equipment because there is no such equipment in the battalion command post. Instead, an extensive support system has been developed to aid the simulation controllers. The software includes movement, terrain, weather, engagement, and other relevant tactical models that compute unit positions and engagement outcomes. Hardware includes consoles for Blue and Red controllers and software management, a mainframe computer, and peripheral equipment. The software and hardware support displays and procedures that allow the simulation controllers to enter Red and Blue movement commands, monitor movements, and keep track of engagement outcomes.

CATTS provides little performance assessment or data collection support for researchers or instructors. Instructors view the action and can provide feedback to the command team during the exercise if appropriate. More often, feedback is provided during debriefings following the multiday exercises. Individual and team performance data are collected in the form of videotapes that record command group behavior. The videotape system is independent of the computer system, however, so attempts to correlate behavioral events with software events are laborious.

Naval Warfare Gaming System (NWGS)

The NWGS is currently under development and will be delivered to the US Naval War College when completed. The detailed statement of requirements (References 23, 24, 25) called for a computerized system to provide training in tactical command decision-making for students and for operational command staffs. The system will consist of a number of terminals tied to a time-sharing computer. The terminals will present alphanumeric and graphic information on CRT screens, and will also be able to provide hard copies of the displayed information. Umpires will have large-screen displays depicting the tactical situation.

The primary function of the software will be to automate many of the functions that have typically been performed by experts operating and observing a manual war game:

- Movement of tactical units
- Sensor reports

- Electronic and acoustics support and countermeasures effects
- Weapons effects and battle damage assessment
- Supply levels and logistics procedures
- Own and threat tactical doctrine

Instead of using the above types of information directly, the umpires will monitor events and make inputs only when they judge that it is necessary to do so. Umpires will also have the capability to change the game rate to rates other than real-time (faster or slower, as appropriate), and make discrete time steps in either direction. They may replay events to provide feedback for participants, or go forward to bypass periods of low activity.

The NWGS will support a wide range of games (Reference 26). The primary categories of games will be:

- Weapon-system-level games--These games will enable individuals and small groups of students to study the capabilities of specific naval weapons and sensor systems and the effects of changes in system parameters.
- One-on-one engagement level games--These games will be characterized by relatively limited areas of operations and short periods of play. The games will be used for analyzing engagements between tactical units (for example, submarine vs submarine, ASW aircraft vs submarine, attack aircraft vs surface ship).

- <u>Full-scale games</u>--These games will be at the task force level, and will cover relatively large, perhaps global, areas of operation.

There will be three types of one-on-one engagement level games: Preprogrammed, computer-opposed, and free-play. Preprogrammed games will be a form of CAI in which the computer will lead the participants through a preplanned set of decision points and give feedback following each decision. In computer-opposed games, the participants will control the Blue forces and the computer will follow threat doctrine in controlling Red forces. In free-play games, two groups of participants will oppose each other.

Full-scale games will be one-sided (computer-opposed) or two-sided (free-play).

Games of any of the three types may be played at several levels. Individuals or small groups of students will be able to play small-scale games and serve as their own umpires. Large, full-scale games will involve numerous groups of participants and several umpires. All groups and umpires will be able to communicate individually and by voice. Because the NWGS will be run by a time-sharing system, several independent small-scale games may be played simultaneously.

The software comprising the driver scenario for the games will consist of the following major modules:

- Platform (surface craft, subsurface craft, fixed- and rotary-wing aircraft, spacecraft, shore installations). Platform characteristics include motion capabilities, fuel capacity and consumption rates, electronic and weapons systems, and so forth.
- Electronic systems (sensors, communications)
- Weapon systems (rate of fire, range, reliability, hit probability, kill probability)
- Logistics (amounts of consumables, rate of consumption, and resupply rate)

The majority of forces will usually be divided between two opposing sides. Forces may, however, also be assigned to nations or blocs friendly to one or the other major contestants and/or neutral nations and blocs.

Games will frequently require many tactical elements. A tactical element is a platform or system that is controlled as a unit in the scenario. It may consist of several elements in some cases; a flight of nine aircraft on the same mission may be considered as a single element, for example, rather than as nine elements. Elements are further classified into sets, formations, aggregations, patterns, and movement plans. The specified minimum number of units to be supported by the NWGS is:

Commands	2000
Sets	1500
Formations	100
Aggregations	100
Patterns	200
Movement Plans	200

The software will consist of models and a data base. The data base will be modifiable by authorized personnel who are not computer professionals. Modification of the data base will not affect the structure or function of the models.

The terminals used by participants and instructors will not resemble operational naval equipment. They will be designed to present the type of information that is normally available for tactical decision-making, but the manner of presentation will not match any current systems.

The NWGS is currently being built by Computer Sciences Corporation using a Honeywell Multics computer system.

The NWGS is the largest war gaming simulation with man-in-the-loop which has been attempted to date. The results of the design phase of the program showed it to be within the attainable state of the art.

Summary

The above examples illustrate that the hardware requirements for the prototype research/training device are well within the state of the art. The SGSS and NWGS are important in this context because they consist of commercial equipment. CATTS also uses commercial equipment although the equipment does not interface with C^2 personnel directly.

Many of the recommended software capabilities are also illustrated. The AWACS and SOTAS simulators are capable of displaying realistic radar imagery depicting complex tactical situations. They and the TTS can receive and process operator inputs through function keys and other control devices, and produce realistic responses. The SGSS and TTS incorporate many advanced features for measuring individual and team performance, and provide performance data to researcher/instructors. The SGSS, TTS and AWACS simulators all provide a measure of reconfigurability: the consoles can support various classes of operators and, in the TTS, the mix of console types can be modified to meet special training requirements. CATTS, the SGSS, and to a lesser extent the AWACS simulator, encourage the use of role players to provide superteam training. CATTS and the NWGS come the closest to providing the flexible, two-sided war-gaming capability and EW features recommended in Chapter II.

One of the most important lessons of the examples is that the scenario generation process is extremely difficult. It requires extensive data on system capabilities, operational procedures, and decision processes and criteria, and the data are often very difficult to obtain. The AWACS SEPPs, TTS problems, and CATTS, NWGS, and SOTAS scenarios all require a substantial effort to develop, and will require a significant continuing effort to keep updated. Once the data have been revised, the scenarios must be entered into the software system. This is often a difficult task in itself, although the SGSS, CATTS, and the NWGS have been designed to facilitate such changes.

RECOMMENDATION

The recommended AFC^2T^2 research facility should be designed by incorporating the best features of the simulators described above, as well as the SAINT language. The integration of these design features should proceed in parallel with an analysis of specific AFC^2T^2 applications and the research designs of specific AFC^2T^2 studies. The number of applications and studies should be limited to as few as possible to keep the analysis manageable, but should also represent a domain of problems or issues so that growth and expansion of the research effort will be possible without major changes in resource requirements or direction. Research issues to be addressed through the use of the recommended facility are discussed in Volumes II and III, and are summarized in the following chapter.

AD-A114 378 HONEYWELL SYSTEMS AND RESEARCH CENTER MINNEAPOLIS MN F/G 5/9
TEAM TRAINING FOR COMMAND AND CONTROL SYSTEMS. VOLUME IV. RECOM--ETC(U)
APR 82 J A MODRICK, S R HOLLINGSWORTH F33615-79-C-0025

UNCLASSIFIED AFHRL-TP-82-10 NL

2 .. 2

AD
A 114378

END
DATE
FILMED
6 82
DTIC

CHAPTER V

RESEARCH APPLICATIONS

The recommended AFC^2T^2 research facility will be used to support empirical research into a variety of areas, as summarized in Table 1. The facility would consist of the hardware and software modules discussed in Chapter II. These modules are summarized in Table 2. The technical difficulty of developing each module, as discussed in Chapter IV, is also shown in the table.

Not all modules are required for all research projects. By identifying the minimum set of features required for preliminary research in each area, a simulator development plan can be formulated. Low-risk features required for a large number of high-priority research projects should be designed and procured early in the simulator acquisition cycle. High-risk features that are required for a smaller number of lower-priority research projects should be deferred until later. This developmental strategy increases the probability for an early payoff--in the form of C^2T^2 research data--while ensuring that the system can grow to meet future research needs.

The following sections briefly summarize each of the issues listed in Table 1, and indicate the simulation capabilities that would be most valuable during the initial phases of research on each topic.

The chapter concludes with a prioritized list of simulation capabilities required for empirical C^2T^2 research.

TABLE 2. MAJOR HARDWARE AND SOFTWARE MODULES FOR THE RECOMMENDED AFC^2T^2 RESEARCH FACILITY

Module	Technical Difficulty
User control consoles	L
Processing equipment	L
C^2 communication network model	M
Subteam models	M
Superteam models	H
Own-aircrew models	M
Aerial combat tactics models	H
Air weapons models	L
Sensor systems models	L
ECM/ECCM models	H
Tactical situation models	H
Training support functions	H

*Level of technical difficulty (as discussed in Chapter IV):
L = Low, M = Medium, H = High

PERFORMANCE MEASUREMENT FOR C^2 OPERATORS, TEAMS, AND SYSTEMS

The set of performance measurement problems should receive the highest priority research attention because so many other issues depend on the

existence of quantitative, reliable, valid, automated performance measurement techniques. The performance measurement issues have been organized into four groups:

- Individual--What product and process measures characterize the performance of individual C^2 team members?
- Team--What product and process measures characterize the performance of C^2 teams?
- System Effectiveness--How can C^2 system effectiveness in a tactical environment be assessed?
- Contribution of Individual and Team Performance to System Effectiveness--What proportion of variance in C^2 system effectiveness is accounted for by individual and team performance?

The minimum simulator capabilities required to begin addressing these problems are summarized in Table 3.

C^2T^2 PROGRAM OBJECTIVES AND REQUIREMENTS

The recommended research facility can be used as one tool in the analysis of C^2T^2 program objectives and requirements. Four research topics of this type that could be explored through the use of the research facility are:

- Media Selection Analysis--Which skills and procedures are best trained through simulation exercises?

TABLE 3. MINIMUM SET OF SIMULATION MODULES REQUIRED TO SUPPORT RESEARCH IN PERFORMANCE MEASUREMENT FOR C^2 OPERATORS, TEAMS, AND SYSTEMS

Research Projects	User control consoles	Processing equipment	C^2 communication network	Subteam models	Superteam models	Own-aircrew models	Aerial combat tactics models	Air weapons models	Sensor systems models	ECM/ECCM models	Tactical situation models	Training support functions
• Individual performance measurement	x	x	-	-	-	x	-	-	-	-	-	-
• Team performance measurement	x	x	x	-	-	x	x	-	-	-	x	-
• System effectiveness measurement	x	x	x	-	-	x	x	x	x	x	x	x
• Contribution of individual and team performance to system effectiveness	x	x	x	-	-	x	x	x	x	x	x	x

KEY

x = Partial or full capability required
- = Capability not required

- Sequencing of Instructional Material--In what order and at what level of detail should simulation exercises treat course topics?

- Interaction of Team Type and Task Type with Instructional Strategy--What are the most effective strategies to be used in applying simulation exercises to various types and levels of teams and various task types?

- Development of Representative Problem Sets--What are the features of effective tactical problems and how should they be presented?

Minimum simulator capabilities required to begin addressing these problems are summarized in Table 4.

C^2T^2 SIMULATION EXERCISE REQUIREMENTS

The research facility could be used in assessing procedures for determining exercise requirements for a variety of training contexts. Research projects and issues that would benefit from the use of the facility are:

- Definition of Training Requirements for Simulation Exercises--What simulation facilities and capabilities are required for meeting various training objectives?

- Physical Fidelity--What are the important determinants of physical fidelity, and what level of physical fidelity is required for various applications?

TABLE 4. MINIMUM SET OF SIMULATION MODULES REQUIRED TO SUPPORT RESEARCH IN C^2T^2 PROGRAM OBJECTIVES AND REQUIREMENTS

Research Projects	User control consoles	Processing equipment	C^2 communication network	Subteam models	Superteam models	Own-aircrew models	Aerial combat tactics models	Air weapons models	Sensor systems models	ECM/ECCM models	Tactical situation models	Training support functions
• Media selection analyses	x	x	-	-	-	x	-	-	-	-	-	-
• Sequencing of instructional material	x	x	-	-	-	x	-	-	-	-	x	x
• Interaction of team type and task type with instructional strategy	x	x	x	-	-	x	-	-	-	-	x	x
• Development of representative problem sets	x	x	x	-	-	x	x	x	x	x	x	x

KEY

x = Partial or full capability required
- = Capability not required

- Tactical Fidelity--What are the important determinants of tactical fidelity, and what level of tactical fidelity is required for various applications?

- Automated Operator and Team Performance Assessment--What performance measurement capabilities can be incorporated into simulation exercises and what are the benefits of doing so?

- Feedback Techniques--What are the most effective ways to provide performance feedback to C^2 operators and teams during simulation exercises?

- War Gaming--To what extent should two-sided, free-play war-gaming capabilities be incorporated into simulation exercises, and what are the best techniques for doing so?

- Part-Whole Task Exercises--What advantages and economies can be achieved by developing a set of exercises that treat parts of the operator or team task rather than one exercise that attempts to cover the entire task?

Minimum simulator capabilities required to begin assessing these problems are summarized in Table 5.

MAN-MACHINE DESIGN FOR C^2 SYSTEMS

The recommended research facility has the potential for serving as a test bed for system developers in the early stages of acquiring new C^2 systems.

TABLE 5. MINIMUM SET OF SIMULATION MODULES REQUIRED TO SUPPORT RESEARCH IN C^2T^2 SIMULATION EXERCISE REQUIREMENTS

Research Projects	User control consoles	Processing equipment	C2 communication network	Subteam models	Superteam models	Own-aircrew models	Aerial combat tactics models	Air weapons models	Sensor systems models	ECM/ECCM models	Tactical situation models	Training support functions
• Definition of training requirements	x	x	-	-	-	x	-	-	-	-	x	-
• Physical fidelity	x	x	-	-	-	x	-	-	-	-	x	-
• Tactical fidelity	x	x	x	-	-	x	x	x	x	x	x	-
• Automated operator and team performance assessment	x	x	-	-	-	x	-	-	-	-	x	x
• Feedback techniques	x	x	-	-	-	x	-	-	-	-	x	x
• War gaming	x	x	x	x	x	x	x	x	x	x	x	x
• Part-whole task exercises	x	x	x	-	-	x	-	-	-	-	x	x

KEY

x = Partial or full capability required
\- = Capability not required

Issues that could be treated during this process are:

- Interaction of Team Type and Task Type--What team types and structures are most appropriate for the types of C^2 tasks/functions to be performed by the system?
- Information Flow Analysis--What are the inputs to and outputs from the system, and how is the information to be processed by the components and personnel within the system?
- Functional Allocation--Which functions should be allocated to hardware and software components and which to personnel; how should the personnel functions be allocated among sub-teams and individuals?
- Operator and Team Decision Aids--What types of decision aids should be developed for operators and teams, and how will they affect performance?
- Operator and Team Consoles, Communication Nets, and Procedures--How should these items be designed to maximize system effectiveness?

Minimum simulator capabilities required to begin assessing these problems are summarized in Table 6.

AUTOMATED C^2T^2 TRAINING SUPPORT FUNCTIONS

As discussed in Chapter III, automated training support functions offer the potential for improving the quality of instructional programs and the efficiency of instructor time. Specific research areas that need

TABLE 6. MINIMUM SET OF SIMULATION MODULES REQUIRED TO SUPPORT RESEARCH IN MAN-MACHINE DESIGN FOR C^2 SYSTEMS AND TEAMS

Research Projects	User control consoles	Processing equipment	C^2 communication network	Subteam models	Superteam models	Own-aircrew models	Aerial combat tactics models	Air weapons models	Sensor systems models	ECM/ECCM models	Tactical situation models	Training support functions
• Interaction of team type and task type	x	x	x	-	-	x	x	x	x	x	x	x
• *Information flow analysis*	x	x	x	x	x	x	x	x	x	x	x	x
• Functional allocation	x	x	-	-	-	x	-	-	-	-	x	x
• Operator and team decision aids	x	x	-	-	-	x	-	-	-	-	x	x
• Operator and team consoles, communication nets, and procedures	x	x	-	-	-	x	-	-	-	-	x	x

KEY

x = Partial or full capability required
- = Capability not required

to be addressed are:

- Assessment of Operator and Team Performance--What are the most effective procedures for assessing student and team performance during training?
- Maintenance of Performance Records--What are the most appropriate records to store, how should they be organized, and how should instructional personnel gain access to them?
- Control of Lesson and Exercise Sequencing--What methods can be developed for sequencing instructional events on the basis of student and team performance?
- Adaptive Training and Testing--How can training systems adapt the level and pacing of instructional events to student team performance, and what is the payoff for doing so?
- Monitoring and Guidance of Student Performance--What automated techniques can be developed to guide students and teams through instructional programs, and what effect will these techniques have on the productivity of training programs?

Minimum simulator capabilities required to begin addressing these problems are summarized in Table 7.

PERSONNEL REQUIREMENTS FOR C^2 TEAMS

The research facility can be used in assessing personnel requirements for C^2 teams. Specific issues are:

- Prerequisite Skill and Knowledge Requirements--Can the requirement for specific aptitude, skills, and knowledge for C^2 team members be demonstrated empirically?

TABLE 7. MINIMUM SET OF SIMULATION MODULES REQUIRED TO SUPPORT RESEARCH IN AUTOMATED C^2T^2 TRAINING SUPPORT FUNCTIONS

Research Projects	User control consoles	Processing equipment	C^2 communication network	Subteam models	Superteam models	Own-aircrew models	Aerial combat tactics models	Air weapons models	Sensor systems models	ECM/ECCM models	Tactical situation models	Training support functions
• Assessment of operator and team performance	x	x	-	-	-	x	-	-	-	-	-	-
• Maintenance of performance records	x	x	-	-	-	x	-	-	-	-	-	x
• Control of lesson and exercise sequencing	x	x	-	-	-	x	-	-	-	-	-	x
• Adaptive training and testing	x	x	-	-	-	x	-	-	-	-	-	x
• Monitoring and guidance of student performance	x	x	-	-	-	x	-	-	-	-	x	x

KEY

x = Partial or full capability required
\- Capability not required

- Remediation Techniques--If entry-level students are deficient in prerequisite skills and knowledge, what are the most efficient techniques for providing remediation?

Minimum simulator capabilities required to begin assessing these problems are summarized in Table 8.

SUMMARY

Tables 3 through 8 indicate that partial capabilities for operator consoles, simulation control consoles, central/distributed processing equipment, and own-aircrew models are required for all listed research problems. These capabilities should therefore be developed early in the simulator acquisition process. Tactical situation models and training support functions are next in terms of general utility. The training support functions related to automated performance measurement and recordkeeping would be of particular value to data collection in all research projects and should be given high development priority for that reason. The remaining simulation features, listed in descending order of priority, are: 1) C^2 communication network models; 2) aerial combat tactics models; 3) air weapons, sensor systems, and ECM/ECCM models; and 4) subteam and superteam models. As a summary, Table 9 lists the simulation capabilities in order of priority. (Level of priority is based on the number of issues, as listed in Table 1, requiring each module.)

TABLE 8. MINIMUM SET OF SIMULATION MODULES REQUIRED TO SUPPORT RESEARCH IN PERSONNEL REQUIREMENTS FOR C^2 TEAMS

Research Projects	User control consoles	Processing equipment	C 2 communication network	Subteam models	Superteam models	Own-aircrew models	Aerial combat tactics models	Air weapons models	Sensor systems models	ECM/ECCM models	Tactical situation models	Training support functions
• Prerequisite skill and knowledge requirements	x	x	-	-	-	x	-	-	-	-	x	-
• Remediation techniques	x	x	-	-	-	x	-	-	-	-	x	x

KEY

x = Partial or full capability required
- = Capability not required

TABLE 9. PRIORITIZED LIST OF MAJOR HARDWARE AND SOFTWARE MODULES FOR PROTOTYPE RESEARCH/ TRAINING DEVICE

Module	Priority
User control consoles	1 (highest)
Processing equipment	1
Own-aircrew models	1
Tactical situation models	2
Training support functions	2
C^2 communication network model	3
Aerial combat tactics models	4
Air weapons models	5
Sensor system models	5
ECM/ECCM models	5
Subteam models	6
Superteam models	6 (lowest)

If only the top-priority modules (from Table 9) are available, research in the following areas (from Table 1) can begin:

- Individual performance measurement (basic research on performance measurement)
- Media selection analyses
- Assessment of operator and team performance (research on techniques for automated performance assessment)

If second-priority modules are added, research in the following areas can begin:

- Sequencing of instructional material
- Definition of training requirements
- Physical fidelity
- Automated operator and team performance assessment (in simulation exercises)
- Feedback techniques
- Functional allocation
- Operator and team consoles, communication nets, and procedures
- Maintenance of performance records
- Control of lesson and exercise sequencing
- Adaptive training and testing
- Monitoring and guidance of student performance
- Prerequisite skill and knowledge requirements
- Remediation techniques

If third-priority modules are added, research in the following areas can begin:

- Interaction of team type and task type with instructional strategy
- Part-whole task exercises

Basic research in team performance measurement techniques in the AFC^2 context can begin if fourth-priority modules are added.

If fifth-priority modules are added, research in the following areas can begin:

- System effectiveness measurement
- Contribution of individual and team performance to system effectiveness
- Development of representative problem sets
- Tactical fidelity
- Interaction of team type and task type

Finally, the following topics can be addressed if sixth-priority modules are added:

- War gaming
- Information flow analysis

Detailed research on all topics will require the complete set of hardware and software modules.

REFERENCES

1. Federman, P.F. and Siegel, A.I., "Communications as a Measurable Index of Team Behavior," Applied Psychological Services, Wayne, Pennsylvania, 1965.

2. Siegel, A.I. and Wolf, J.J., "Digital Simulation of the Performance of the Intermediate-Size Crew," Technical Report ASP-7071-5, Applied Psychological Services, Wayne, Pennsylvania, 1971.

3. Siegel, A.I., Wolf, J.J., and Lanterman, R.S., "Digital Simulation of Crew Performance: Validation of a Digital Simulation Model for Crew Performance Simulation," Applied Psychological Services, Wayne Pennsylvania, 1970.

4. Siegel, A.I., Wolf, J.J., and Sorenson, R.T., "Techniques for Evaluating Overload in Man-Machine Systems: Evaluation of One- or Two-Operator System Evaluative Model Through a Controlled Laboratory Test," Applied Psychological Services, Wayne, Pennsylvania, 1962.

5. Siegel, A.I., Wolf, J.J., and Cosentino, J., "Digital Simulation of the Performance of Intermediate-Size Crews: Application and Validation of a Model for Crew Simulation," Applied Psychological Services, Wayne, Pennsylvania, 1971.

6. Siegel, A.I. and Wolf, J.J., "Digital Simulation of Submarine Crew Performance, II. Computer Implementation and Initial Results of the Application of a Psychosocial 'Model' for Digitally Simulating Crew Performance," Applied Psychological Services, Wayne, Pennsylvania, 1965.

7. Chubb, G.P., "Using Monte Carlo Simulation to Assess the Impact Radiation Induced Performance Degradation Can Have on Mission Success," <u>Symposium on Computer Simulation as Related to Manpower and Personnel Planning</u>, Naval Personnel Research and Development Laboratory, San Diego, California, 1971.

8. Siegel, A.I. and Wolf, J.J., "Techniques for Evaluation Overloading in Man-Machine Systems: A Further Application of a 'Model' for Digital Simulation of One- or Two-Operator Man-Machine Systems," Applied Psychological Services, Wayne, Pennsylvania, 1971.

9. Mills, R.G., "System Modeling and Simulation: Application of a Research Methodology and Test," Unpublished PhD dissertation, Ohio State University, Columbus, Ohio, 1976.

10. Duket, S.D., Seifert, D.J., and Wortman, D.B., "SAINT Simulation of a Remotely-Piloted Vehicle/Drone Facility," AMRL-TR-119, Wright Patterson AFB, Ohio, 1976.

11. Kuperman, G. and Seifert, D., "Development of a Computer Simulation Model for Evaluating DAIS Display Concepts," Proceedings of 19th Annual Meeting of the Human Factors Society, 1975, pp. 347-353.

12. Pew, R.W., Baron, S., Feehrer, C.E., and Miller, D.C., Review and Analysis of Performance Models Applicable to Man-Machine Systems Evaluation, AFOSR-TR-77-0520. Cambridge, Massachusetts: Bolt, Beranek and Newman, Inc., 1977.

13. Butler, A.K. and Frye, C.H., "PLANIT Language Reference Manual," TM-(L)-4422/002/01, 7 October 1970. With supplement by C.H. Frye, 1978.

14. Frye, C.H., "PLANIT System Operator's Manual. Comprehensive Computer Operator's Guide to Operating the PLANIT System Through Version 4.1," 1 October 1978. The Northwestern Regional Educational Laboratory, Portland, Oregon, November 1978.

15. Litton Data Systems, Inc., "PLANIT Utility Program (TTSPUP) User Manual for TACFIRE Advanced Training Program," Report 148002-901, 15 December 1978.

16. Litton Data Systems, Inc., "User Manual for PLANIT Support Software for TACFIRE Advanced Training Program," Report 148002-902A, 26 October 1979.

REFERENCES (continued)

17. Litton Data Systems, Inc., "TACFIRE/PLANIT Author Handbook for the TACFIRE Advanced Training Program," Report 148002-903A, 31 October 1979.

18. Litton Data Systems, Inc., "TACFIRE/PLANIT Student Handbook for the TACFIRE Advanced Training Program," Report 148002-904A, 12 December 1979.

19. Litton Data Systems, Inc., "TACFIRE/PLANIT Operator Handbook for the TACFIRE Advanced Training Program," Report 148002-905A, 12 June 1979.

20. Barber, H.F. and Kaplan, I.T., "Battalion Command Group Performance in Simulated Combat," Technical Paper 353, United States Army Research Institute, Fort Leavenworth, Kansas, 1979.

21. Torres, R.H., "Methodology for Evaluation of the United States Army Combined Arms Tactical Training Simulator (CATTS)," Naval Post-Graduate School, Monterey, California, 1978.

22. TRW Systems Group, "Mathematical Model User's Manual Combined Arms Tactical Training Simulator (CATTS), Device 16A3," Technical Report: NAVTRAEQUIPCEN 73-C-0156-E003, Naval Training Equipment Center, Orlando, Florida, 1977.

23. United States Naval War College, "Detailed Statement of Requirements for a War Gaming Support System," Naval War College, Newport, Rhode Island, 1975.

24. Naval Surface Weapon Center: Statement of Work for the Naval Warfare Gaming System. Naval Electronic Systems Command, Washington, D.C., 1976.

25. Computer Sciences Corporation, Program Performance Specification (PPS) for Naval War Gaming System (NWGS). Naval Electronic Systems Command, Washington, DC, 1979.

REFERENCES (concluded)

26. Pacer Systems, Inc., "Representative Scenarios for NWC War Gaming: Vol. 1, Weapon System Level Analysis; Vol. 2, One-on-One Engagement Level Games; Vol. 3, Student Full-Scale Game; Vol. 4, Command Level Games;" Naval Electronic System Command, Washington, D.C., 1976.

ATE
LMED

8